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Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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3 **Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from**
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5 **291 cross-sectional surveys**
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ABSTRACT

Background: More than two decades of conflict and natural disasters in Somalia have resulted in one of the largest and longest running humanitarian crises in the world.

Nutrition data has been collected over the years despite challenges to inform programmatic action. This paper explores malnutrition and morbidity trends in Somalia during the last decade, disaggregated by geographical zone and livelihood system.

Methods: We used data from 291 cross-sectional surveys conducted in children aged 6-59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting prevalences over time were analysed by geographic area, livelihood system and season. Logistic regressions were used to test trends.

Results: Morbidity showed a declining trend, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in northern Somalia. The wasting trends show a striking peak in 2011, more marked in southern and central Somalia (SCZ) and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among Internally Displaced Persons (IDPs).

Pastoralist showed the lowest stunting estimates overall, while agrarian populations showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by all outcomes. Seasonality affected the three outcomes differently by livelihood system. Stunting rates increased after the 2011 famine for all age groups within children under five years.

Conclusions: Despite the continuous complex situation in Somalia, there has been a sustained decline in stunting and morbidity in the last decade. Wasting trends have

1
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3 remained at very high levels especially in north-east and the south zones of Somalia. The
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5 findings support the importance of performing trend analyses disaggregated by zone and
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7 livelihood groups within countries, to better identify priorities for program intervention.
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13 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

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16 • The sample characteristics in terms of size and number of surveys allowed for a
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18 high precision in the analysis and for the stratification by livelihood system.
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20 However, despite the enhanced precision of the estimates of malnutrition and
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22 morbidity showed by the narrow confidence intervals, due to the effects of
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24 confounding and bias (measurement and or recall bias) inherent in cross sectional
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26 and nutritional surveys, the analysis may produce spuriously precise but biased
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28 estimates of association and stability.
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33 • The so called IDPs livelihood was over-represented in the overall population as
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35 recent data indicated that the proportion of IDPs in Somalia population was around
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37 14% (36), thus the importance of the stratified analysis.
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41 • Data were collected in field conditions, which may have an impact on the accuracy
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43 of measurements, although the FSNAU survey enumerators' long-time experience
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45 and routinely training may have minimized this limitation.
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49 • Accurate age estimation is a major problem as there are no accurate records of
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51 birth and age determination mostly relies on maternal recall. As a result, recall bias
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53 in child morbidity and stunting could have occurred due to reliance on maternal
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55 recall.
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BACKGROUND

Somalia has been experiencing one of the longest-running humanitarian crises in the world. It has suffered protracted war and conflict, political instability, disruption of economy and humanitarian assistance, and extreme climatic conditions since collapse of state institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the country suffered a famine, more than 250,000 people are estimated to have died of starvation and approximately 53% of the population experienced food crisis. An estimated 200,00 people had also died during a previous famine in 1991/1992 (1).

On top of the two mentioned famines, the rates of acute malnutrition have remained at very high levels since the start of the conflict, and they are among the highest in the world today. The causes of different forms of malnutrition in Somalia are multi-factorial and linked not only to food insecurity but also to morbidity and inadequate caring practices, all of them related to the disruption of peoples livelihood, destitution, large-scale population displacement and the limited access to basic services (2) (3) (4) (5).

Nutrition response programming has been taking place in Somalia for decades, in the form of live-saving interventions like distribution of food and cash, treatment of acute malnutrition, targeted supplementary feeding, and emergency public health measures during disease outbreaks, as well as in the form of livelihoods, recovery and development programmes in agriculture, livestock, water, and environment in order to improve resilience among vulnerable populations (6). However, effectiveness of humanitarian assistance continues to be constrained by prevailing insecurity which restricts access and delivery of aid to some areas.

The Food Security and Nutritional Analysis Unit (FSNAU) has been conducting national nutrition surveillance in Somalia since the year 2000 in order to monitor the nutritional

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3 status of the population and inform program interventions. FSNAU has been collecting
4 data through different surveillance systems including nutrition surveys, rapid Mid-Upper
5 Arm Circumference (MUAC) assessments, passive health facility-based screening and at
6 some times and places by sentinel site surveillance. In 2009 FSNAU carried out a meta-
7 analysis study including a systematic review of findings and raw data analysis of surveys
8 conducted by FSNAU and partners in Somalia for the period 2001-2008 focusing on
9 wasting trends and casual factors (7). In addition, in 2012 WFP released a report
10 analysing trends of food and nutrition insecurity in Somalia for the period 2007-2012 (8).
11 Since then, no other systematic review of the nutrition data collected by FSNAU has been
12 published.
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27 The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in
28 describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice
29 yearly depending on the year). They combine results from different data collection
30 methods to assess the overall nutrition situation, and focus on the identification of
31 malnutrition hotspots and on closely following up specific population groups such as IDP
32 settlements or particular livelihood zones (9).
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42 The three geographic zones of Somalia have been affected differently by the conflict,
43 being the South-central zone (SCZ) historically the most affected one, whereas the North
44 West (NWZ) and the North East zones (NEZ) have been generally more stable, with better
45 governance and institutional capacities. Three main livelihood systems are present in
46 Somalia: pastoralists, agro-pastoralists and riverine. The North west, east and central
47 parts of the country are predominantly pastoral, while some regions in the south in addition
48 to pastoralists also have agro-pastoral and riverine livelihood systems (10). The prevailing
49 insecurity in the SCZ also triggered large-scale displacement of population and according
50 to the latest United Nations High Commissioner for Refugees (UNHCR) Forced
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3 Displacement report, among the 1.5 million IDPs estimated in 2016, 893,000 were located
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5 in the SCZ (11).
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9 Food security and nutrition outcomes are importantly affected by seasonality in Somalia as
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11 well, with annual crop and livestock production dependent on the two main rainy seasons:
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13 *Gu* (April-June) and *Deyr* (October-December). Seasonality impacts the general
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15 availability of food and the rates of infection, among other things. Thus, understanding the
16
17 typical seasonal fluctuations is useful for predicting changes in malnutrition and morbidity
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19 rates (12).
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24 The aim of this study is to explore and interpret observed trends in malnutrition (wasting
25
26 and stunting) and morbidity by zone, livelihood system and season of analysis for the
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28 2007-2016 period, giving special attention to the effects of the 2011 famine on the
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30 malnutrition outcomes for the rest of the period.
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33 34 **METHODS**

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37 The data used for this study were obtained from 291 surveys undertaken by FSNAU and
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39 partners working in Somalia. All surveys included in this study had similar design (two
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41 stage cross-sectional surveys) and comparable probability sampling methods. They were
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43 carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.
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47 There are four main seasons defined by rainfall patterns in Somalia: the *Gu*, the main rainy
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49 season (April to June), the *Hagaa*, a short and cool dry season (July to September), the
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51 *Deyr*, the short rainy season (October to December), and the long and hot dry season
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53 called the *Jilaal* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr*
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55 seasons were taken into account for the analysis.
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3 Somalia has been divided into three main UN operational zones: Northwest, Northeast and
4 South-Central, with varied social, livelihood and economic structures. These zones
5 generally correspond to current administrative and political designations known,
6 respectively, as Somaliland, Puntland and other Federal Member States of the Federal
7 Government of Somalia. The North West zone comprising the pre-war regions of Woqooyi
8 Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes
9 the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug,
10 Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo
11 and Banadir regions.
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24 There are three main livelihoods in the country, broadly defined by common characteristics
25 of the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists
26 practise mixed crop and livestock production; and riverine live in the South Central
27 irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13).
28 Agropastoralists and riverine livelihoods are classified as Agropastoral in this analysis as
29 both are mainly sedentary and share similar characteristics in terms of their primary
30 dependence on crop cultivation as opposed to reliance on rearing livestock. Because of
31 the presence of a significant proportion of internally displaced population in the country,
32 FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and
33 these were coded as a further livelihood category, although it does not constitute a
34 livelihood system in *sensu stricto*. Although FSNAU also collects data on selected urban
35 populations (mostly Kismayo and Mogadishu), these were not included in our analysis.
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52 Since 2007 and for both technical and operational purposes, FSNAU has conducted rural
53 livelihood-based surveys as opposed to administrative boundary-based surveys. A
54 livelihood zone map of Somalia was created based on climate, topography, natural
55 resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the
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3 32 rural livelihood zones were consolidated into 18, reasonably homogenous rural
4 livelihood zones. See maps attached in Annex 1 (14).
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8 The surveys were conducted at livelihood zone level or main IDP settlement based on
9 multi-stage cluster sampling with probability proportional to size (PPS) design covering all
10 livelihood zones that were accessible at the time of the survey. The primary sampling units
11 were the villages which were selected randomly from a list of all the villages in each
12 livelihood, and the second unit of analysis were the households within the sample villages,
13 which were randomly selected using the Standardized Methodology for Survey in Relief
14 and Transition (SMART). Sample selection and sizes of the surveys (number of
15 households and number of children) were calculated using the Emergency Nutrition
16 Assessment (ENA) software (Version 2011, July 9, 2015). Previous estimations of wasting
17 measured by weight-for-height and crude mortality rates for the surveyed areas were used
18 for the sample size calculations, separately for anthropometry and mortality. The higher of
19 these two sample sizes was used to determine the final sample size as the surveys
20 integrate both anthropometry and mortality. An additional 2-3% was added to the sample
21 size to allow for dropout or refusal to participate
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41 As there are livelihood zones that geographically cross the three operational zones taken
42 into account for this analysis (like Coastal Deeh crossing the SCZ and the NEZ or Hawd
43 Pastoral crossing the SCZ and the NWZ, see maps in Annex 1), we went down to the
44 villages level in order to allocate children surveyed to the corresponding operational zone
45 according to the geographical location. In each zone, surveys were aggregated according
46 to the livelihood system of the livelihood zone they represented (example, West Golis
47 Pastoral and Guban Pastoral livelihood zones in the NWZ would be aggregated in the
48 Pastoral sub-sample of the NWZ, according to 2014 livelihood zone distribution).
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3 Although in most of the time points (season/year) of the study period we had
4 representative data for each livelihood, due to field work restrictions in some specific
5 season/years not all livelihoods systems were covered. Therefore, and in order to
6 construct the trends for the whole period of analysis the missing values in-between the
7 trend were imputed. The imputation method we used was logistic regression to calculate
8 the predictions and the residuals. Missing values in the beginning of the trend (year 2007
9 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were
10 imputed. Supplementary Table 1 in Annex 2 presents the compiled sample sizes of the
11 population analysed in each time point, disaggregated by livelihood and zone.
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24 The data were cleaned by deleting the records of individual children with any of the
25 following criteria: age < 6 months (n=5), age > 59 months (n=6), and missing age (n=1137),
26 sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-for-height z-
27 score (WHZ) and length/height-for-age z-score (HAZ) were calculated using World Health
28 Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using WHO 2006
29 growth standards. Extreme biologically implausible values were excluded based on WHO
30 standards with recommended flag limits of WHZ (n=545) and HAZ (n=824) scores below -
31 5 or above +5 (15).
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43 Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-
44 scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition
45 defined as height-for-age below -2 Z-scores (16). Child morbidity was assessed based on
46 a 2-week recall of the incidence of diarrhoea, acute respiratory infection (ARI) and febrile
47 illness and 30-days recall for suspected measles. A new variable called morbidity was
48 created and coded as 1 if the child had a positive response to at least one of the four
49 illnesses and as 0 if the child had a negative response to all of the four illnesses. We
50 calculated the prevalence of wasting, morbidity and stunting for each of the surveys
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3 separately and provided the levels of uncertainty in the estimates with the 95% confidence
4 intervals (CI).
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8 We graphed the estimations and confidence intervals of wasting, stunting and morbidity for
9 each year and season disaggregated by livelihood group and geographical zone for the
10 patterns comparison over the 10-year time period.
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14 In order to analyse the observed trends, we created two differentiated time periods, one
15 before the famine of 2011 (including data from 2007 to 2010), and another one covering
16 the time period after the famine (2012-2016). Logistic regressions were used to test the
17 change of the nutrition and health outcomes with each additional year in each of the two
18 periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for
19 the overall period. All analyses were stratified by livelihood system and geographical zone.
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Odd ratios (ORs) and confidence intervals (CI) were calculated.

To explore the potential impact of the wasting peaks recorded during the 2011 famine on
the subsequent stunting estimations, we created six artificial cohorts based on the
children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children
who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36
months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort
(Cohort08) was constructed by selecting children that were 6-12 months in the year 2008,
13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in
2012. Following the corresponding procedure, we constructed the rest of the cohorts for
the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and
we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the
child (x-axis), highlighting the position of the 2011 famine in order to facilitate the
interpretation of results. Due to data availability this analysis was restricted to the
agropastoral and pastoralists populations of the South Central zone.

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3 Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.
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6 **Ethical approval**

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9 Ethical approval was provided through permission by the Ministry of Health (MOH)
10 Somalia, Transitional Federal Government of Somalia Republic, Ref:
11 MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were
12 presented and discussed with MOH and partners prior to the conduct of each seasonal
13 assessment. Owing to the high illiteracy rate of the population, informed verbal consent
14 was sought from all participating households and individuals.
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23 **RESULTS**

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26 A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were
27 examined from 2007 to 2016. The North West and North East zones of the country were
28 mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South
29 Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine
30 livelihoods (See Table 1).
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39 Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49
40 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia
41 Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and
42 period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%)
43 and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the
44 2011 year of famine, and 64% after year 2011.
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53 In Table 1 are summarized the children's characteristics by zone.
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Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	24.4	39.2	39.5
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall ¹	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

¹Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in morbidity

The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

In Figure 1 we observe the jagged patterns of morbidity estimations, with peaks over 50% in several time points (season/year) for the pastoralists and IDP populations.

Pastoralists showed in the NWZ a significant increase in morbidity for each additional year until 2010 (Table 2) and two important peaks in the *Deyr* seasons of 2015 and 2016, while in the NEZ values for pastoralists have been steadily between 30 and 40% since *Deyr*

2012. In the SCZ, however, there was a significant decrease of morbidity during the whole period of analysis for pastoralists, more marked during the second period (0.8 decrease per each additional year, see Table 2), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 2. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figure 2 shows, in the NWZ, a steady decline in wasting estimates for all livelihoods and periods of analysis. Agropastorals' estimates declined to around 5% at the end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among IDPs also increased sharply in 2016 in this particular zone.

In the NEZ, there was an important decrease in wasting estimates for each additional year until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 3, although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has remained above 10% among pastoralists and above 15% among IDPs (Figure 2B).

Figure 2C shows the wasting estimates for the SCZ above 15% for the three livelihoods in most of the years, and the peak of wasting prevalence above 35% in year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists, although it was sustained longer in time. In the second period of analysis, starting in 2012, there was a slight decrease on wasting for each additional year (see Table 3).

In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods, although the difference was more marked for pastoralists and IDPs.

Table 3. Trend analysis on wasting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
North East Zone			
Trend per year			
2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
South Central Zone			
Trend per year			
2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)

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Trends in stunting

For the first period of analysis (2007-2010) the stunting estimates have decreased significantly for each additional year in the three zones and all livelihoods (See Figure 3 and Table 4) although in the NWZ there was a peak for pastoralists observed in Gu 2010, and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

During the second period of analysis, there was a small peak of stunting in year 2012 in the NWZ for all livelihoods but ever since estimates have been declining steadily in this zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure 3 B). The stunting estimates among pastoralists are approximately a third of the IDPs in this zone during the whole period of analysis.

Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists, below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016. Pastoralists show the lower stunting rates overall.

Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

Table 4. Trend analysis on stunting per period of analysis and season

		Agropastoral	Pastoral	IDPs
North West Zone				
Trend per year				
	2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
	2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
North East Zone				
Trend per year				
	2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)
	2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season				
	Deyr (Oct.-Dec.)	-	Ref.	Ref.
	Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
South Central Zone				
Trend per year				
	2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
	2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

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3 Figure 4 represent the growth patterns based on height for age, showing the stunting rates
4 by age group for the six self-constructed cohorts in the agro-pastoral and pastoral
5 livelihoods of the SCZ (See Methods section for details). In both livelihoods and all
6 cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in
7 most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the
8 Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the
9 initial peak at 24 months, and the Coh2008 which despite initial decline after the 24
10 months' peak, experiences a later increase among the children 49-59 months of age.
11 Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09
12 for which the stunting prevalence increased or decreased only slightly respectively after
13 the first 24 months' peak.
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29 The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper
30 declines in stunting prevalence after initial peak at 13-24 months of age and throughout all
31 the older age groups.
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DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (18), but also infectious diseases are identified as main drivers of malnutrition in Somalia (2) (9).

Our results show that even if morbidity declined during the period of analysis, prevalence were still high, especially among IDPs. Pervasive morbidity is associated with limited access and utilisation of basic health and water services and IDPs reside in temporary infrastructures and crowded conditions, which exacerbate their vulnerability to infectious diseases (19). Also, and for all the livelihood groups, the morbidity trends showed numerous peaks reflecting disease outbreaks such as measles, polio, acute watery diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains “the largest known reservoir of unvaccinated children in a geographic area in the world”

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3 (around half a million children)(20). The rise in morbidity observed in 2016 corresponds
4 with the cholera and measles outbreaks occurring in that year (21) (22) which further
5 contributed to the rise in acute malnutrition and mortality which reached near-famine
6 thresholds at the start of 2017, only averted by the large-scale and sustained humanitarian
7 actions (23).
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15 In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow
16 onset of drought driven by four consecutive rain failures, which together with some of the
17 most violent conflict and restricted humanitarian access in Somalia's history contributed to
18 the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and
19 agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The
20 situation was further aggravated by the economic crisis, characterized by currency
21 devaluation, disrupted trade and market activities, and hyperinflation of basic food and
22 non-food items (24), and by al-Shabaab's blocking of humanitarian operations in areas
23 under their control (25). It is estimated that nearly 260 000 people died during the 2011
24 famine(26), half of them children.
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39 After the 2011 peak the wasting prevalence dropped from the extremely high levels
40 registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the
41 period, still a very high prevalence which flags the threshold for emergency according to
42 the World Health Organization (27). The pronounced decrease was the result of the
43 intense humanitarian actions but could also be reflecting the increased under five mortality
44 in 2011, which affected severely acutely malnourished children primarily, and that peaked
45 at 5.83 deaths per 10,000 in the South Central zone (28). The SCZ was the most affected
46 by the 2011 famine and shows the highest wasting levels for all livelihoods in the
47 consequent years. This zone is impacted by higher intensity of conflict, flooding of the
48 riverine areas, continued displacements, restrictions of movements and goods due to clan
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3 and religious insurgency, and low availability and poor quality of health services (29).

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5 Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They
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7 are considered to be among the poorest population groups in the country and their
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9 vulnerability to malnutrition is highly linked to poor access to food, income, health care,
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11 and safe water coupled with high morbidity burden (30). In this group, our results show the
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13 raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in
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15 early 2017 (23) previously mentioned. Stunting estimates are also consistently higher
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17 among IDPs, especially in the NEZ and the SCZ.
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22 Nevertheless, the overall pattern of stunting is a declining trend for all livelihood groups in
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24 the three zones. Pastoralists' children seem to be more resilient to stunting, with estimates
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26 consistently lower, reaching very low levels (below 5%) in all three zones at the end of the
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28 period. Other studies have suggested this is a result of the physical stature of Somali
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30 pastoralists as tall and lean, which may mask the actual estimates of chronic malnutrition
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32 (31), but decreasing trends are clear nonetheless. Another potential explanation for this
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34 differentiation is that pastoral groups have relatively better asset base and access to
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36 animal products, especially milk and cow's blood, which provide high protein diets even
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38 when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients
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40 will favour continued height growth rather than soft tissue. The opposite applies for
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42 agriculturalists as energy may be provided by cereals but protein and micronutrient intake
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44 may be compromised, favouring stunting but less wasting (32).
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50 Also important to notice is the stunting peak consistently shown for all livelihoods in the
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52 immediate years after the famine, probably reflecting the effects in stunting of the
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54 extremely high rates of wasting.
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58 These same observations are replicated in the results of the agro-pastoralists and
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60 pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently

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3 lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as
4 compared to the agro-pastoral ones, and a relation is observed between the high wasting
5 peak in 2011 and the stunting in the subsequent years.
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10 The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24
11 months of age, is consistent with the growth faltering observed in other deprived
12 populations of the world, which show a stunting crowning around 24 months of age which
13 decreases thereafter (33). The interpretation of childhood catch-up after 24 months is that
14 a combination of the normal postnatal maturation of the children's immune systems and
15 the development of a broad range of adaptive responses against previously encountered
16 pathogens reduces the frequency and severity of growth-impairing infections (34). This is
17 the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However,
18 among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012,
19 which encompasses the children born after the 2011 famine. In all the rest of the cohorts
20 the growth pattern changes, as the stunting prevalence experiences a sharp increase a
21 year after the children have experienced the 2011 famine, independently of the age of the
22 children during that period. This suggests a strong impact of the high wasting rates in the
23 subsequent stunting prevalences. This association has been shown in longitudinal studies
24 that have reported that children with wasting or negative changes in weight for height are
25 at greater risk of linear growth retardation (35).
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48 **CONCLUSIONS**

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51 The international community has been implementing humanitarian, recovery and
52 development programmes for the Somali population in a complex and varied environment
53 for the last decade, with ambivalent results.
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58 Although wasting and morbidity prevalence remained high during the period of analysis
59 there was a slight but clear decreasing trend for both indicators, only reversed at the end
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3 of the period, 2016, when severe drought conditions impacted most parts of the country.
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5 Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.
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8 The association found between high wasting prevalence and subsequent high stunting
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10 estimates calls for a more holistic response which addresses humanitarian life-saving
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12 needs and development work simultaneously.
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16 Moreover, the focus on reducing malnutrition in Somalia clearly needs to move away from
17
18 the short-term response aimed at addressing acute food insecurity and treatment of
19
20 acutely malnourished children to a more integrated response that includes access to clean
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22 water, the promotion of hygiene and sanitation, and the improvement of access to basic
23
24 health services among its priorities.
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27 28 **Authors' contributions**

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31 RCM & EC were involved in all stages from the conception and design, data acquisition,
32
33 analysis and interpretation. FK and DB contributed to the study design, the data analysis
34
35 and interpretation. DM & AY were responsible for conducting the surveys and managing
36
37 the data. All authors have critically reviewed and approved the final version of the article.
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39

40 41 **Competing interests**

42
43
44 The authors declare that they have no competing interests.
45
46

47 48 **Funding**

49
50 Not applicable.
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53 54 **Availability of data and material**

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56 The data that support the findings of this study are available from FSNAU but restrictions
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58 apply to the availability of these data, which were used under license for the current study,
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3 and so are not publicly available. Data are however available from the authors upon
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5 reasonable request and with permission of FSNAU.
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8 **Patient and Public Involvement** 9

10
11 Not patients were involved in the study. Results of the nutrition and mortality surveys
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13 conducted in Somalia are used for programmatic actions targeting the study participants
14
15 (children under 5 years of age), but due to the characteristics of the study population there
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17 is no specific action planned to disseminate results directly to them.
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20 **Acknowledgements** 21

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23 Not applicable.
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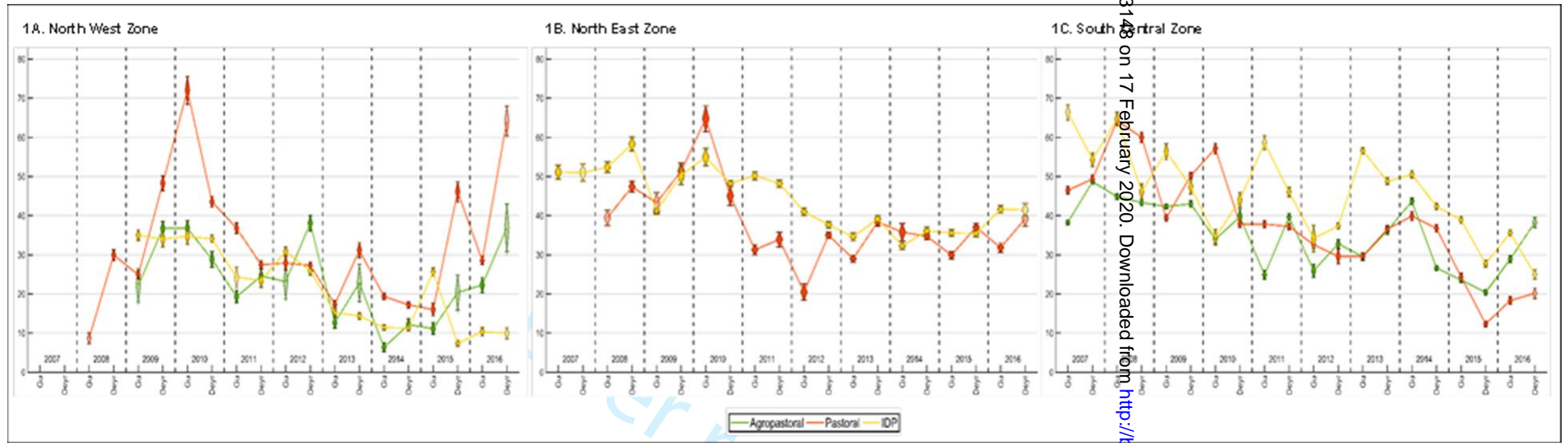
FIGURE'S LEGENDS

Figure 1: Morbidity estimates and confidence intervals at 95% by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ).

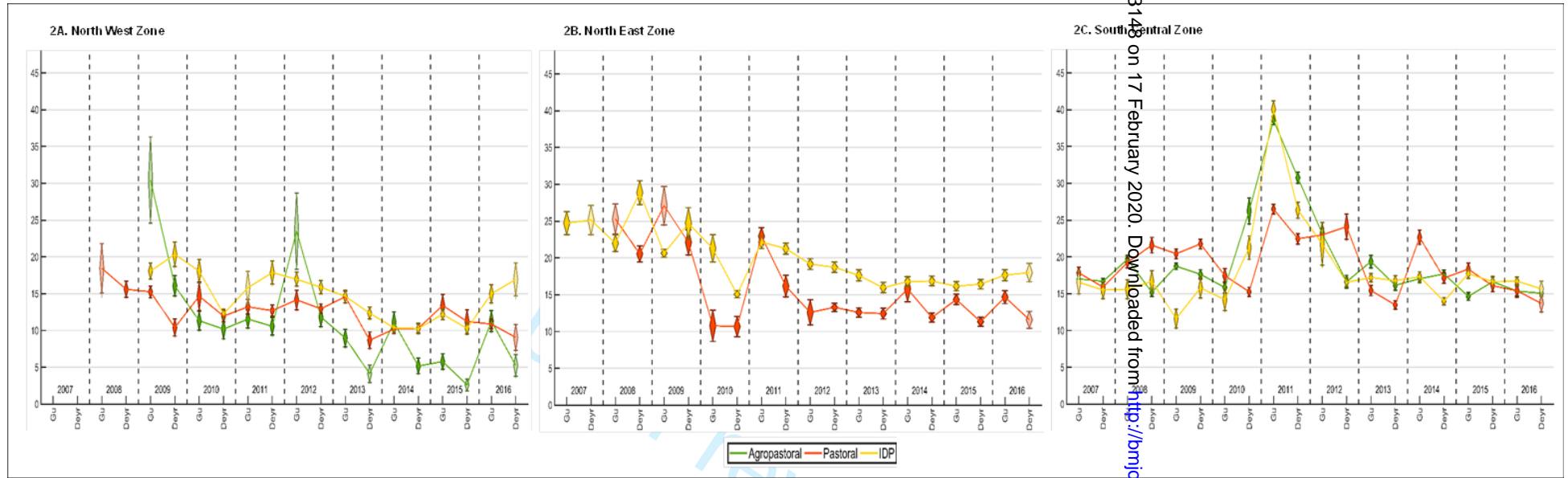
Figure 2: Wasting estimates and confidence intervals at 95% by year and season of analysis for each livelihood and disaggregated in the three operational zones (NWZ, NEZ and SCZ).

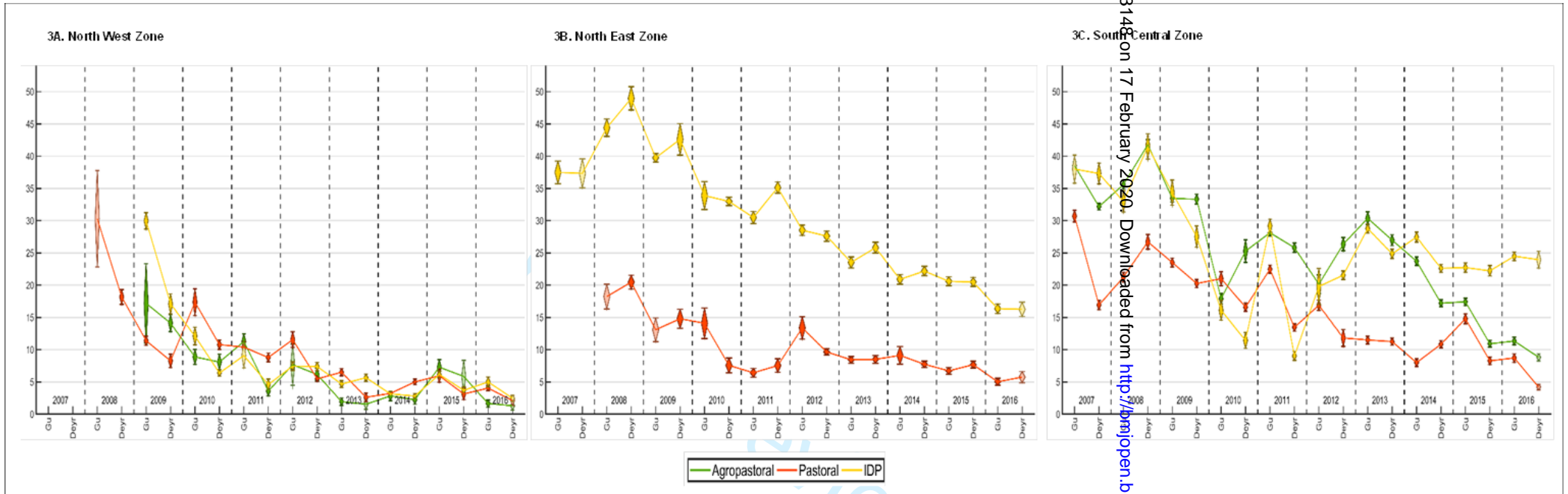
Figure 3. Estimates of stunting with 95% confidence intervals by year and season of analysis, for each livelihood disaggregated in the three operational zones (NWZ, NEZ and SCZ).

Figure 4. Growth patterns cohorts of children 6-59 months in agro-pastoralists and pastoralists populations in the South Central zone of Somalia

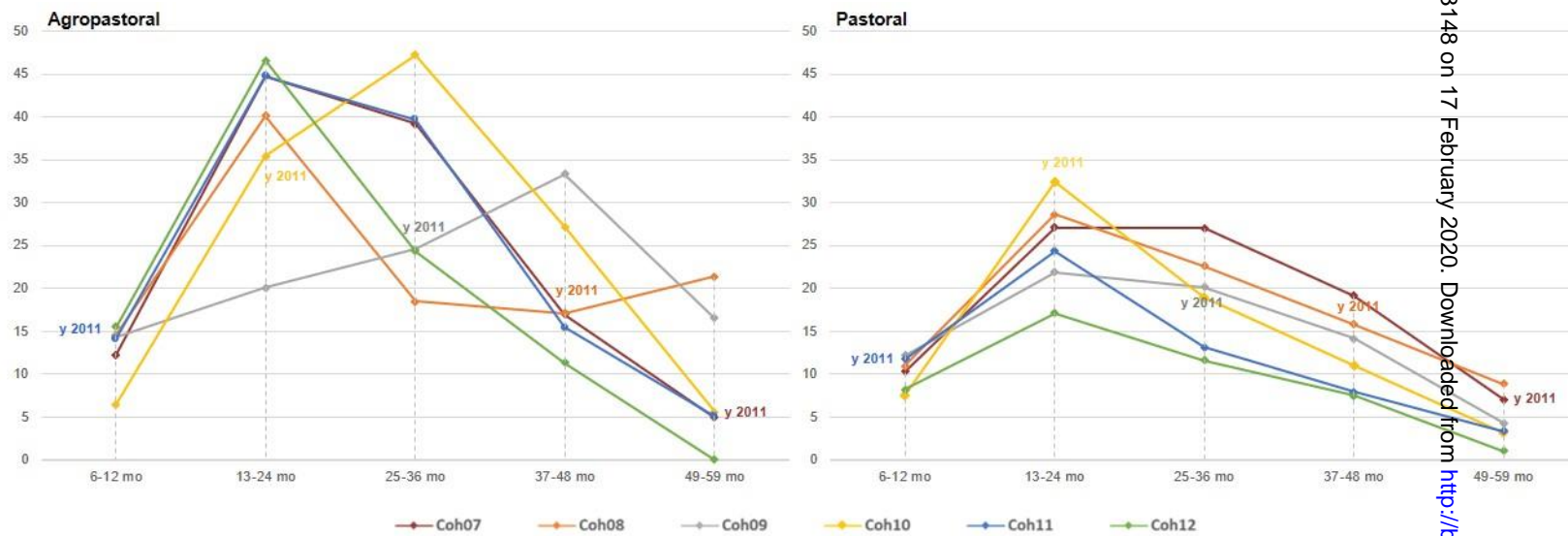


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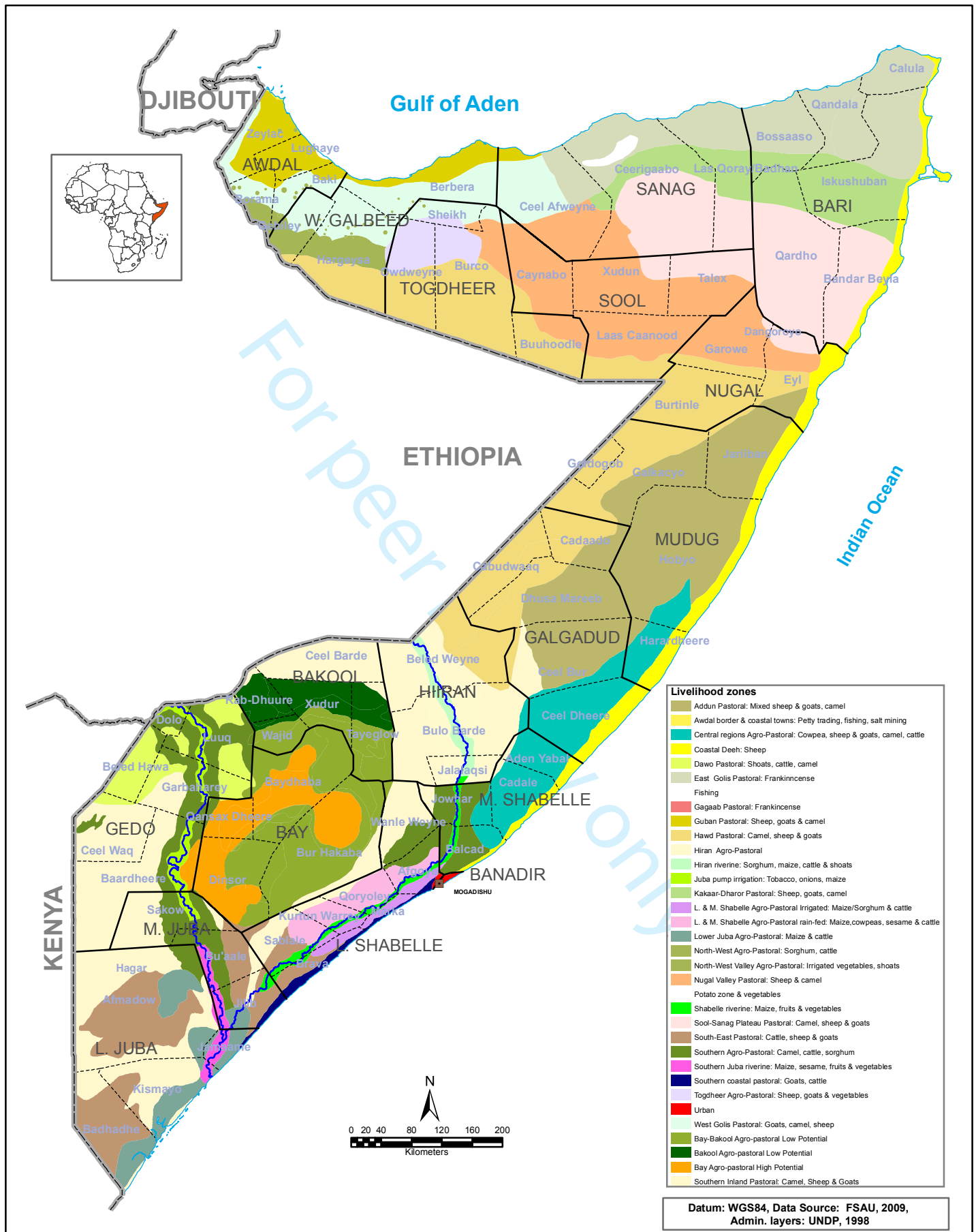


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Review only

SOMALIA: LIVELIHOOD ZONES



Technical Partner

Funding Agencies

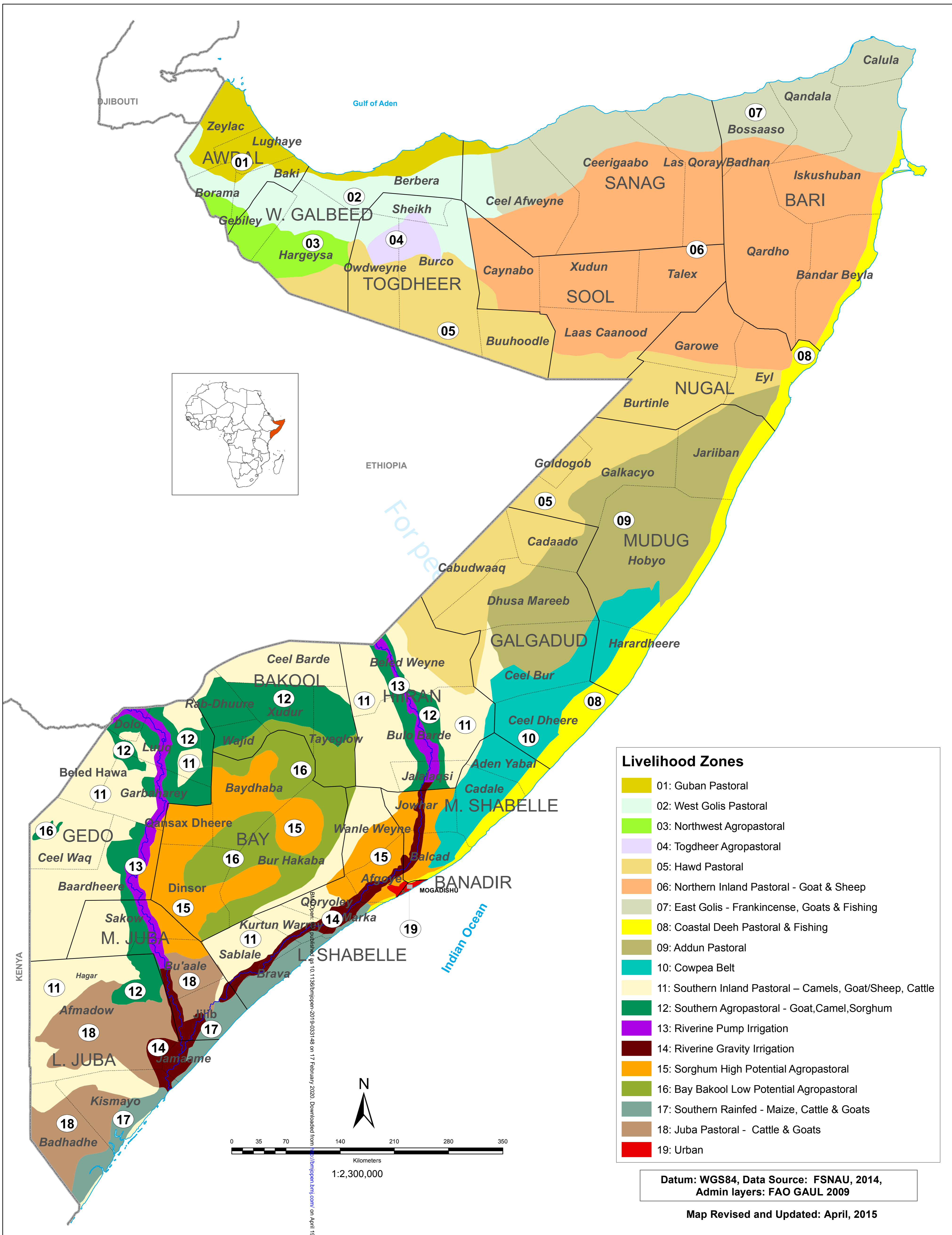


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The boundaries and names on these maps do not imply official endorsement or acceptance by the United Nations. The regional & District boundaries reflect those endorsed by the Government of the Republic of Somalia in 1986.

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Annex 2

Supplementary Table 1: Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu			
North West																				49585
Agropastoral					716	609	520	684	643		617	568			496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				69275
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2083	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658	2913	3210	3393	3222	2574	45987
South Central																				163654
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,755	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,199	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,411	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16436	17873	23204	18694	15888	16312	282514

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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 &10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear	

		which confounders were adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

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3 1 **Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from**
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5 2 **291 cross-sectional surveys**
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8 3 Martin-Cañavate R^{1§}, Custodio E^{1*}, Yusuf A², Molla D², Fasbender D¹ and Kayitakire F¹
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20 7 §The first two authors have contributed equally to the manuscript.
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21 **ABSTRACT**

22 **Background:** More than two decades of conflict and natural disasters in Somalia have
23 resulted in one of the longest running humanitarian crises in the world. Nutrition data has
24 been collected over the years despite challenges to inform programmatic action. This
25 paper explores malnutrition and morbidity trends in Somalia during the last decade,
26 disaggregated by geographical zone and livelihood system.

27 **Methods:** We used data from 291 cross-sectional surveys conducted in children aged 6-
28 59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting
29 prevalences over time were analysed by geographic area, livelihood system and season.
30 Logistic regressions were used to test trends.

31 **Results:** The wasting trends show a striking peak in 2011, more marked in southern and
32 central Somalia (SCZ) and coinciding with the famine declaration. The trend declines
33 slightly thereafter although not consistently across all zones and livelihoods, and it raises
34 again in 2016 especially among Internally Displaced Persons (IDPs). Stunting declined for
35 all groups and in all zones, but with more consistent patterns in northern Somalia.
36 Morbidity also showed a declining trend, although with multiple peaks depicting disease
37 outbreaks.

38 Pastoralist showed the lowest stunting estimates overall, while agrarian populations
39 showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by
40 all outcomes. Seasonality affected the three outcomes differently by livelihood system.
41 Stunting rates increased after the 2011 famine for all age groups within children under five
42 years.

43 **Conclusions:** Despite the continuous complex situation in Somalia, there has been a
44 sustained decline in stunting and morbidity in the last decade. Wasting trends have

1
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3 45 remained at very high levels especially in north-east and the south zones of Somalia. The
4
5 46 findings support the importance of performing trend analyses disaggregated by zone and
6
7 47 livelihood groups within countries, to better identify priorities for program intervention.
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11 48

12 13 14 49 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 15
16 50
- 17 50 • The sample characteristics in terms of size and number of surveys allowed for a
18
19 51 high precision in the analysis and for the stratification by livelihood systems,
20
21 52 although the so called IDPs livelihood was over-represented
 - 22
23 53 • Data were collected in field conditions, which may have an impact on the accuracy
24 53 of measurements, although survey teams were consistently trained and equipment
25
26 54 precision regularly monitored to avoid it.
 - 27
28 55 • Accurate age estimation was problematic as there were no accurate records of birth
29
30 56 and age determination mostly relied on maternal recall.
 - 31 56 • Data quality validation was carried out daily by running the ENA plausibility checks
32
33 57 and after each data collection data vetting was conducted by the Assessment and
34
35 58 Information Management Working Group in Somalia.
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62 BACKGROUND

63 Somalia has been experiencing a long humanitarian crisis for the past two decades. It has
64 suffered protracted war and conflict, political instability, disruption of economy and
65 humanitarian assistance, and extreme climatic conditions since collapse of state
66 institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the
67 country suffered a famine, more than 250,000 people are estimated to have died of
68 starvation and approximately 53% of the population experienced food crisis. An estimated
69 200,000 people had also died during a previous famine in 1991/1992 (1).

70 On top of the two mentioned famines, the rates of acute malnutrition have remained at
71 very high levels since the start of the conflict, and they are among the highest in the world
72 today. The causes of different forms of malnutrition in Somalia are multi-factorial and
73 linked not only to food insecurity but also to morbidity and inadequate caring practices, all
74 of them related to the disruption of peoples livelihood, destitution, large-scale population
75 displacement and the limited access to basic services (2) (3) (4).

76 Nutrition response programming has been taking place in Somalia for decades, in the form
77 of live-saving interventions like distribution of food and cash, treatment of acute
78 malnutrition, targeted supplementary feeding, and emergency public health measures
79 during disease outbreaks, as well as in the form of livelihoods recovery and development
80 programmes in agriculture, livestock, water, and environment in order to improve resilience
81 among vulnerable populations (5). However, effectiveness of humanitarian assistance
82 continues to be constrained by prevailing insecurity which restricts access and delivery of
83 aid to some areas.

84 The Food Security and Nutritional Analysis Unit (FSNAU) is an FAO project with the
85 mission to conduct national nutrition surveillance in Somalia since the year 2000 in order

1
2
3 86 to monitor the nutritional status of the population and inform program interventions.
4
5 87 FSNAU has been collecting data through different surveillance systems including nutrition
6
7
8 88 surveys, rapid Mid-Upper Arm Circumference (MUAC) assessments, passive health
9
10 89 facility-based screening and, at some times and places, by sentinel site surveillance.
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13 90 In 2009 FSNAU carried out a meta-analysis study including a systematic review of findings
14
15
16 91 and raw data analysis of surveys conducted by FSNAU and partners in Somalia for the
17
18 92 period 2001-2008 focusing on wasting trends and casual factors (6). In addition, in 2012
19
20 93 WFP released a report analysing trends of food and nutrition insecurity in Somalia for the
21
22
23 94 period 2007-2012 (7). Since then, no other systematic review of the nutrition data collected
24
25 95 by FSNAU has been published.
26
27

28 96 The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in
29
30
31 97 describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice
32
33 98 yearly depending on the year). They combine results from different data collection
34
35 99 methods to assess the overall nutrition situation, as well as to identify malnutrition hotspots
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37
38 100 and to closely follow-up specific population groups such as internally displaced populations
39
40 101 (IDP) or particular livelihood zones (8).
41
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43 102 The three operational zones of Somalia have been affected differently by the conflict,
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45
46 103 being the South-central zone (SCZ) historically the most affected one, whereas the North
47
48 104 West (NWZ) and the North East zones (NEZ) have been generally more stable, with better
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50 105 governance and institutional capacities. The three main livelihood systems present in
51
52
53 106 Somalia are unevenly distributed across the country. Pastoralists are mainly distributed in
54
55 107 the north west, east and central parts, while agro-pastoralists and riverine livelihood
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57 108 systems mostly in the South. (9). The prevailing insecurity has also triggered large-scale
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60 109 displacement of populations, and settlements of internally displaced populations (IDPs) are

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3 110 found all over Somalia, but in the SCZ predominantly. According to the latest United
4
5 111 Nations High Commissioner for Refugees (UNHCR) Forced Displacement report, among
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7
8 112 the 1.5 million IDPs estimated in 2016, 893,000 were located in the SCZ (10).
9

10
11 113 Food security and nutrition outcomes are importantly affected by seasonality in Somalia as
12
13 114 well, with annual crop and livestock production dependent on the two main rainy seasons
14
15 (Gu and Deyr). Seasonality impacts the general availability of food and the rates of
16 115
17
18 116 infection, among other things. Thus, understanding the typical seasonal fluctuations is
19
20 117 useful for predicting changes in malnutrition and morbidity rates (11).
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24 118 Assessing the fluctuations in malnutrition by season within the year, over time year-to-
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26 119 year, and differentiated by livelihood group is essential to facilitate interpretation of the
27
28 120 situation and target effective interventions, as shown by a similar exercise conducted in
29
30 121 the Greater Horn of Africa region (12).
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34 122 The aim of this study is to explore and interpret observed trends in malnutrition (wasting
35
36 123 and stunting) and morbidity by operational zone, livelihood system and season of analysis
37
38
39 124 for the 2007-2016 period, giving special attention to the effects of the 2011 famine on the
40
41 125 malnutrition outcomes for the rest of the period.
42

43 44 45 126 **METHODS**

46
47 127 The data used for this study were obtained from 291 surveys undertaken by FSNAU and
48
49
50 128 partners working in Somalia. All surveys included in this study had similar design (two
51
52 129 stage cross-sectional surveys) and comparable probability sampling methods. They were
53
54 130 carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.
55

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57 131 There are four main seasons defined by rainfall patterns in Somalia: the *Gu*, the main rainy
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59 132 season (April to June), the *Hagaa*, a short and cool dry season (July to September), the
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3 133 *Deyr*, the short rainy season (October to December), and the long and hot dry season
4
5 134 called the *Jilaa* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr*
6
7 seasons were taken into account for the analysis.
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11 136 Somalia has been divided into three main UN operational zones: Northwest, Northeast and
12
13 137 South-Central, with varied social, livelihood and economic structures. These zones
14
15 138 generally correspond to current administrative and political designations known,
16
17 respectively, as Somaliland, Puntland and other Federal Member States of the Federal
18 139 Government of Somalia. The North West zone comprising the pre-war regions of Woqooyi
19
20 140 Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes
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22 141 the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug,
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24 142 Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo
25
26 143 and Banadir regions.
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31
32 145 The three main livelihoods in the country are broadly defined by common characteristics of
33
34 146 the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists
35
36 practise mixed crop and livestock production; and riverine live in the South Central
37 147 irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13).
38
39 148 Agropastoralists and riverine livelihoods are classified as *Agropastoral* in this analysis as
40
41 149 both are mainly sedentary and share similar characteristics in terms of their primary
42
43 dependence on crop cultivation as opposed to reliance on rearing livestock. Because of
44 150 the presence of a significant proportion of internally displaced population in the country,
45
46 151 FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and
47
48 152 these were coded as a further livelihood category, although it does not constitute a
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50 153 livelihood system in *sensu stricto*. Although FSNAU also collects data on selected urban
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52 populations (mostly Kismayo and Mogadishu), these were not included in our analysis.
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3 157 Since 2007 and for both technical and operational purposes, FSNAU has conducted rural
4
5 158 livelihood-based surveys as opposed to administrative boundary-based surveys. A
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8 159 livelihood zone map of Somalia was created based on climate, topography, natural
9
10 160 resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the
11
12 161 32 rural livelihood zones were consolidated into 18, reasonably homogenous rural
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14
15 162 livelihood zones. Detailed maps can be found at
16
17 163 <http://www.fsnau.org/products/maps/livelihood-maps> (14).
18
19

20 164 The surveys were conducted at livelihood zone level or main IDP settlement based on
21
22 165 multi-stage cluster sampling with probability proportional to size (PPS) design covering all
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24
25 166 livelihood zones that were accessible at the time of the survey. The primary sampling units
26
27 167 were the villages (clusters) which were selected randomly from a list of all the villages in
28
29 168 each livelihood zone, and the second unit of analysis were the households within the
30
31
32 169 sample villages, which were randomly selected using the Standardized Methodology for
33
34 170 Survey in Relief and Transition (SMART). Households and villages were assumed to
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36 171 follow the livelihood of the livelihood zone in which they were located. Sample selection
37
38 172 and sizes of the surveys (number of households and number of children) were calculated
39
40
41 173 using the Emergency Nutrition Assessment (ENA) software (Version 2011, July 9, 2015).
42
43 174 Previous estimations of wasting measured by weight-for-height and crude mortality rates
44
45 175 for the surveyed areas were used for the sample size calculations, separately for
46
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48 176 anthropometry and mortality. The higher of these two sample sizes was used to determine
49
50 177 the final sample size as the surveys integrate both anthropometry and mortality. An
51
52 178 additional 2-3% was added to the sample size to allow for dropout or refusal to participate
53
54
55 179 As there are livelihood zones that geographically cross the three operational zones taken
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57 180 into account for this analysis (like Coastal Deeh crossing the SCZ and the NEZ or Hawd
58
59
60 181 Pastoral crossing the SCZ and the NWZ, see maps in

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3 182 <http://www.fsnao.org/products/maps/livelihood-maps>), we went down to the clusters level
4
5 183 in order to allocate children surveyed to the corresponding operational zone according to
6
7
8 184 the geographical location. In each zone, surveys were aggregated according to the
9
10 185 livelihood system of the livelihood zone they represented (example, West Golis Pastoral
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12 186 and Guban Pastoral livelihood zones in the NWZ would be aggregated in the Pastoral sub-
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14
15 187 sample of the NWZ, according to 2014 livelihood zone distribution).

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18 188 Although in most of the time points (season/year) of the study period we had
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20 189 representative data for each livelihood, due to field work restrictions in some specific
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22 190 season/years not all livelihoods systems were covered. Therefore, and in order to
23
24 191 construct the trends for the whole period of analysis the missing values in-between the
25
26
27 192 trend were imputed. The imputation method we used was logistic regression to calculate
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29 193 the predictions and the residuals. Missing values in the beginning of the trend (year 2007
30
31 194 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were
32
33
34 195 imputed. Supplementary Table 1 in Annex 1 presents the compiled sample sizes of the
35
36 196 population analysed in each time point, disaggregated by livelihood and zone.

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39 197 Data was collected by FSNAU survey enumerators, who are recruited locally from health
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41 198 centers, clinics etc. and are trained for five days before every survey as part of FSNAU's
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44 199 quality assurance process. FSNAU surveys are coordinated by FSNAU Nutrition Field
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46 200 Analysts and technical experts from the Ministries of Health, and data quality is validated
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48 201 in a daily basis by running the ENA plausibility checks. At the end of data collection there
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50
51 202 is a technical vetting conducted by the Assessment and Information Management Working
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53 203 Group established under the Somalia Nutrition Cluster for data coordination and quality
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55 204 control of nutrition surveys.

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58 205 The data were cleaned by deleting the records of individual children with any of the
59
60 206 following criteria: age < 6 months (n=5), age > 59 months (n=6), and missing age

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3 207 (n=1137), sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-
4
5 208 for-height z-score (WHZ) and length/height-for-age z-score (HAZ) were calculated using
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7
8 209 World Health Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using
9
10 210 WHO 2006 growth standards. Extreme biologically implausible values were excluded
11
12 211 based on WHO standards with recommended flag limits of WHZ scores below -5 or above
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14
15 212 +5 (n=545) and HAZ scores below -6 or above +6 (n=824)(15).

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18 213 Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-
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20 214 scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition
21
22 215 defined as height-for-age below -2 Z-scores (16). *Severe wasting* is defined as WHZ below
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24
25 216 -3 and/or the presence of nutritional oedema, thus severe wasting is included in the
26
27 217 wasting definition. We provide the severe wasting estimates independently in Table 1 but
28
29 218 the rest of the tables and figures only report wasting which includes both moderate and
30
31 219 severe forms.

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34 220 Child morbidity was assessed based on a 2-week recall of the incidence of diarrhoea,
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37 221 acute respiratory infection (ARI) and febrile illness and 30-days recall for suspected
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39 222 measles. A new variable called morbidity was created and coded as 1 if the child had a
40
41 223 positive response to at least one of the four illnesses and as 0 if the child had a negative
42
43
44 224 response to all of the four illnesses. We calculated the prevalence of wasting, morbidity
45
46 225 and stunting for each of the surveys separately and provided the levels of uncertainty in
47
48 226 the estimates with the 95% confidence intervals (CI).

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51 227 We graphed the estimations and confidence intervals of wasting, stunting and morbidity for
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54 228 each year and season disaggregated by livelihood group and geographical zone for the
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56 229 patterns comparison over the 10-year time period.

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3 230 In order to analyse the observed trends, we created two differentiated time periods, one
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5 231 before the famine of 2011 (including data from 2007 to 2010), and another one covering
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7
8 232 the time period after the famine (2012-2016). Logistic regressions were used to test the
9
10 233 change of the nutrition and health outcomes with each additional year in each of the two
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12 234 periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for
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15 235 the overall period. All analyses were stratified by livelihood system and geographical zone.
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17 236 Odd ratios (ORs) and confidence intervals (CI) were calculated.

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20 237 To explore the potential impact of the wasting peaks recorded during the 2011 famine on
21
22 238 the subsequent stunting estimations, we created six artificial cohorts based on the
23
24 239 children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children
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26
27 240 who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36
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29 241 months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort
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31 242 (Cohort08) was constructed by selecting children that were 6-12 months in the year 2008,
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33 243 13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in
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36 244 2012. Following the corresponding procedure, we constructed the rest of the cohorts for
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38 245 the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and
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41 246 we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the
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43 247 child (x-axis), highlighting the position of the 2011 famine in order to facilitate the
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45 248 interpretation of results. Due to data availability this analysis was restricted to the
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48 249 agropastoral and pastoralists populations of the South Central zone.

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50 250 Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.

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53 251 Public and patient involvement

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56 252 Not patients were involved in the study. Results of the nutrition and mortality surveys
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59 253 conducted in Somalia are used for programmatic actions targeting the study participants
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3 254 (children under 5 years of age), but due to the characteristics of the study population there
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6 255 is no specific action planned to disseminate results directly to them.
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8 256 Access to survey sites was agreed with local authorities and community leaders in the
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11 257 districts where the clusters were sampled. Verbal consent for all caregivers of the sampled
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13 258 children was sought before administration of the questionnaire. Children who were found
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15 259 as severely malnourished or with any other medical problem during the survey were
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18 260 referred to the nearest health facility for medical attention and appropriate treatment using
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20 261 referral form.
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23 262 Ethical approval was provided through permission by the Ministry of Health (MOH)
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25 263 Somalia, Transitional Federal Government of Somalia Republic, Ref:
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27 264 MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were
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30 265 presented and discussed with MOH and partners prior to the conduct of each seasonal
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32 266 assessment.
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35 267 **RESULTS**

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38 268 A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were
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40 269 examined from 2007 to 2016. The North West and North East zones of the country were
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43 270 mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South
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45 271 Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine
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47 272 livelihoods (See Table 1).
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50 273 Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49
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52 274 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia
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55 275 Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and
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57 276 period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%)
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and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the 2011 year of famine, and 64% after year 2011.

In Table 1 are summarized the children's characteristics by zone.

Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	24.4	39.2	39.5
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall ¹	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

¹Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figure 1 shows in the first graph, for the NWZ, a steady decline in wasting estimates for all livelihoods and periods of analysis. Agropastorals' estimates declined to around 5% at the

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286 end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among
287 IDPs also increased sharply in 2016 in this particular zone.

288 In the NEZ, there was an important decrease in wasting estimates for each additional year
289 until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 2,
290 although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has
291 remained above 10% among pastoralists and above 15% among IDPs (second graph of
292 Figure 1).

293 The third graph of Figure 1 shows the wasting estimates for the SCZ above 15% for the
294 three livelihoods in most of the years, and the peak of wasting prevalence above 35% in
295 year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists,
296 although it was sustained longer in time. In the second period of analysis, starting in 2012,
297 there was a slight decrease on wasting for each additional year (see Table 2).

298 In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods,
299 although the difference was more marked for pastoralists and IDPs.

Table 2. Trend analysis on wasting per period of analysis and season

	Agropastoral	Pastoral	IDPs	
North West Zone				
Trend per year				
	2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
	2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season				

	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
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North East Zone				
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Trend per year				
	2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
	2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season				
	Deyr (Oct.-Dec.)	-	Ref.	Ref.
	Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
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South Central Zone				
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Trend per year				
	2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
	2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)
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309 Trends in stunting

310 For the first period of analysis (2007-2010) the stunting estimates have decreased
311 significantly for each additional year in the three zones and all livelihoods (See Figure 2
312 and Table 3) although in the NWZ there was a peak for pastoralists observed in Gu 2010,
313 and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

314 During the second period of analysis, there was a small peak of stunting in year 2012 in
315 the NWZ for all livelihoods but ever since estimates have been declining steadily in this
316 zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was
317 observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease
318 thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure
319 2). The stunting estimates among pastoralists are approximately a third of the IDPs in this
320 zone during the whole period of analysis.

321 Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for
322 agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists,
323 below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016.
324 Pastoralists show the lower stunting rates overall.

325 Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

Table 3. Trend analysis on stunting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			

Trend per year				
	2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
	2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
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North East Zone				
<hr/>				
Trend per year				
	2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)
	2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season				
	Deyr (Oct.-Dec.)	-	Ref.	Ref.
	Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
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South Central Zone				
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Trend per year				
	2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
	2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

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3 336 Figure 3 represent the growth patterns based on height for age, showing the stunting rates
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5 337 by age group for the six self-constructed cohorts in the agro-pastoral and pastoral
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7 338 livelihoods of the SCZ (See Methods section for details). In both livelihoods and all
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10 339 cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in
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12 340 most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the
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14 341 Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the
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17 342 initial peak at 24 months, and the Coh2008 which despite initial decline after the 24
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19 343 months' peak, experiences a later increase among the children 49-59 months of age.
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21 344 Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09
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24 345 for which the stunting prevalence increased or decreased only slightly respectively after
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26 346 the first 24 months' peak.
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29 347 The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper
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31 348 declines in stunting prevalence after initial peak at 13-24 months of age and throughout all
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34 349 the older age groups.

35 36 37 350 **Trends in morbidity**

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40 351 The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in
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42 352 the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

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45 353 In Figure 4 we observe the jagged patterns of morbidity estimations, with peaks over 50%
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47 354 in several time points (season/year) for the pastoralists and IDP populations.

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49
50 355 Pastoralists showed in the NWZ a significant increase in morbidity for each additional year
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52 356 until 2010 (Table 4) and two important peaks in the *Deyr* seasons of 2015 and 2016, while
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55 357 in the NEZ values for pastoralists have been steadily between 30 and 40% since *Deyr*
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57 358 2012. In the SCZ, however, there was a significant decrease of morbidity during the whole
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59 359 period of analysis for pastoralists, more marked during the second period (0.8 decrease
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per each additional year, see Table 4), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 4. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

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For peer review only

DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Conflict related violence and insecurity prevent the delivery of humanitarian aid, disrupts livelihoods and breaks down familial and community networks that can provide the necessary support and guidance needed for looking after young children, including their nutritional requirements (18) Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (19), but also infectious diseases are identified as main drivers of malnutrition in Somalia (20).

In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow onset of drought driven by four consecutive rain failures, which together with some of the most violent conflict and restricted humanitarian access in Somalia's history contributed to the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The

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396 situation was further aggravated by the economic crisis, characterized by currency
397 devaluation, disrupted trade and market activities, and hyperinflation of basic food and
398 non-food items (21), and by al-Shabaab's blocking of humanitarian operations in areas
399 under their control (22). It is estimated that nearly 260 000 people died during the 2011
400 famine(23), half of them children.

401 After the 2011 peak the wasting prevalence dropped from the extremely high levels
402 registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the
403 period, still a very high prevalence which flags the threshold for emergency according to
404 the World Health Organization (24). The pronounced decrease was mainly the result of the
405 intense humanitarian actions but could also be reflecting the increased under five mortality
406 in 2011, which affected severely acutely malnourished children primarily, and that peaked
407 at 5.83 deaths per 10,000 in the South Central zone (25) (26). The SCZ was the most
408 affected by the 2011 famine and shows the highest wasting levels for all livelihoods in the
409 consequent years. This zone is impacted by higher intensity of conflict, flooding of the
410 riverine areas, continued displacements, restrictions of movements and goods due to clan
411 and religious insurgency, and low availability and poor quality of health services (27).
412 Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They
413 are considered to be among the poorest population groups in the country and their
414 vulnerability to malnutrition is highly linked to poor access to food, income, health care,
415 and safe water coupled with high morbidity burden (28). In this group, our results show the
416 raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in
417 early 2017 (29) previously mentioned. Stunting estimates are also consistently higher
418 among IDPs, especially in the NEZ and the SCZ.

419 Nevertheless, the overall pattern of stunting is a declining trend for all livelihood groups in
420 the three zones. Pastoralists' children seem to be more resilient to stunting, with estimates

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421 consistently lower, reaching very low levels (below 5%) in all three zones at the end of the
422 period. Other studies have suggested this is a result of the physical stature of Somali
423 pastoralists as tall and lean, which may mask the actual estimates of chronic malnutrition
424 (30), but decreasing trends are clear nonetheless. Another potential explanation for this
425 differentiation is that pastoral groups have relatively better asset base and access to
426 animal products, especially milk and cow's blood, which provide high protein diets even
427 when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients
428 will favour continued height growth rather than soft tissue. The opposite applies for
429 agriculturalists as energy may be provided by cereals but protein and micronutrient intake
430 may be compromised, favouring stunting but less wasting. The higher rates of malnutrition
431 observed among pastoralists in the analysis after the Gu rains may be associated with the
432 restricted access to their typical diet in the precedent Jilal season. During that extended
433 dry season from mid-January to mid-April the pastoralists adult male and adolescent boys
434 migrate with the livestock to distant grazing areas, leaving women and young children
435 behind with limited access to milk and other animal source products (31). And this is
436 consistent with findings from pastoralist populations of other countries in the region (12).
437 And although this may have a more clear impact on wasting as an indicator sensitive to
438 short term changes, our results show the same seasonal fluctuations in stunting estimates,
439 and recent studies are highlighting the role of seasonality as potential risk factor to poor
440 growth among young infants (32).

441 Also important to notice is the stunting peak consistently shown for all livelihoods in the
442 immediate years after the famine, probably reflecting the effects in stunting of the
443 extremely high rates of wasting.

444 These same observations are replicated in the results of the agro-pastoralists and
445 pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently

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446 lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as
447 compared to the agro-pastoral ones, and a relation is observed between the high wasting
448 peak in 2011 and the stunting in the subsequent years.

449 The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24
450 months of age, is consistent with the growth faltering observed in other deprived
451 populations of the world, which show a stunting crowning around 24 months of age which
452 decreases thereafter (33). The interpretation of childhood catch-up after 24 months is that a
453 combination of the normal postnatal maturation of the children's immune systems and the
454 development of a broad range of adaptive responses against previously encountered
455 pathogens reduces the frequency and severity of growth-impairing infections (34). This is
456 the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However,
457 among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012,
458 which encompasses the children born after the 2011 famine. In all the rest of the cohorts
459 the growth pattern changes, as the stunting prevalence experiences a sharp increase a
460 year after the children have experienced the 2011 famine, independently of the age of the
461 children during that period. This suggests a strong impact of the high wasting rates in the
462 subsequent stunting prevalence. This association has been shown in longitudinal studies
463 that have reported that children with wasting or negative changes in weight for height are
464 at greater risk of linear growth retardation (32) (35), and the differentiated patterns for
465 children among pastoralists and agropastoralists populations are consistent with similar
466 studies conducted in the region (12).

467 In relation to morbidity, although it declined during the period of analysis, prevalence were
468 still high, especially among IDPs. Pervasive morbidity is associated with limited access
469 and utilisation of basic health and water services and IDPs reside in temporary
470 infrastructures and crowded conditions, which exacerbate their vulnerability to infectious

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3 471 diseases (36). Also, and for all the livelihood groups, the morbidity trends showed
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5 472 numerous peaks reflecting disease outbreaks such as measles, polio, acute watery
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8 473 diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery
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10 474 diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains “the
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12 475 largest known reservoir of unvaccinated children in a geographic area in the world”
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15 476 (around half a million children). The rise in morbidity observed in 2016 corresponds with
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17 477 the cholera and measles outbreaks occurring in that year (37) (38) which further contributed
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19 478 to the rise in acute malnutrition and mortality which reached near-famine thresholds at the
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22 479 start of 2017, only averted by the large-scale and sustained humanitarian actions (29).

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25 480 As already shown by other studies, the provision of malnutrition and morbidity estimates,
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27 481 when seen in the context of historical values and viewed as specific to different livelihood
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29 482 groups can provide useful timely warning of the need for intervention to mitigate
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32 483 developing nutritional crises (12).

33 34 484 Limitations and strengths of the study

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37 485 The sample characteristics in terms of size and number of surveys allowed for a high
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40 486 precision in the analysis and for the stratification by livelihood system. However, despite
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42 487 the enhanced precision of the estimates of malnutrition and morbidity showed by the
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44 488 narrow confidence intervals, due to the effects of confounding and bias (measurement and
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47 489 or recall bias) inherent in cross sectional and nutritional surveys, the analysis may produce
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49 490 spuriously precise but biased estimates of association and stability.

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52 491 The so called IDPs livelihood was over-represented in the overall population as recent
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54 492 data indicated that the proportion of IDPs in Somalia population was around 14% (36),
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57 493 thus the importance of the stratified analysis.

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494 Data were collected in field conditions, which may have an impact on the accuracy of
495 measurements, although the FSNAU survey enumerators' long-time experience and
496 routinely training may have minimized this limitation.

497 Imputed values have to be interpreted with caution as they can introduce a bias. However,
498 as shown in the figures the imputed values are randomly distributed in the years, zones
499 and livelihood groups studied thus we do not consider they are impacting the trends
500 patterns in a systematic way

501 Accurate age estimation can be a major problem as there are no accurate records of birth
502 in Somalia and age determination mostly relies on maternal recall. However, FSNAU
503 conducted the ENA plausibility checks on every survey to minimize any potential bias and
504 the age distribution in the sample shows the expected distribution.

505

506 CONCLUSIONS

507 The international community has been implementing humanitarian, recovery and
508 development programmes for the Somali population in a complex and varied environment
509 for the last decade, with ambivalent results.

510 Although wasting and morbidity prevalence remained high during the period of analysis
511 there was a slight but clear decreasing trend for both indicators, only reversed at the end
512 of the period, 2016, when severe drought conditions impacted most parts of the country.

513 Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.

514 The association found between high wasting prevalence and subsequent high stunting
515 estimates calls for a more holistic response which addresses humanitarian life-saving
516 needs and development work simultaneously.

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3 517 Moreover the focus on reducing malnutrition in Somalia clearly needs to move away from
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5 518 the short-term response aimed at addressing acute food insecurity and treatment of
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8 519 acutely malnourished children to a more integrated response that includes access to clean
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10 520 water, the promotion of hygiene and sanitation, and the improvement of access to basic
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12 521 health services among its priorities.

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15 522 Finally, the households' vulnerability towards morbidity and malnutrition varies according to
16
17 523 the type of livelihoods they pursue. Significant improvements can only be realized taking
18
19
20 524 into account the specific challenges and opportunities within the various livelihoods across
21
22 525 Somalia.

23 24 25 526 **Authors' contributions**

26
27
28 527 RCM & EC were involved in all stages from the conception and design, data acquisition,
29
30 528 analysis and interpretation. FK and DF contributed to the study design, the data analysis
31
32
33 529 and interpretation. DM & AY were responsible for conducting the surveys and managing
34
35 530 the data. All authors have critically reviewed and approved the final version of the article.
36
37

38 531 **Competing interests**

39
40
41 532 The authors declare that they have no competing interests.
42
43

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45
46
47 534 Not applicable.
48
49

50 535 **Availability of data and material**

51
52
53 536 The data that support the findings of this study are available from FSNAU but restrictions
54
55 537 apply to the availability of these data, which were used under license for the current study,
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57 538 and so are not publicly available. Data are however available from the authors upon
58
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60 539 reasonable request and with permission of FSNAU.

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541 Not applicable.

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655 **FIGURE'S LEGENDS**

656

657 **Figure 1:** Wasting estimates and confidence intervals at 95% (diamond shapes) by year
658 and season of analysis for each livelihood and disaggregated in the three operational
659 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
660 imputed.

661

662 **Figure 2.** Stunting estimates and confidence intervals at 95% (diamond shapes) by year
663 and season of analysis for each livelihood and disaggregated in the three operational
664 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
665 imputed.

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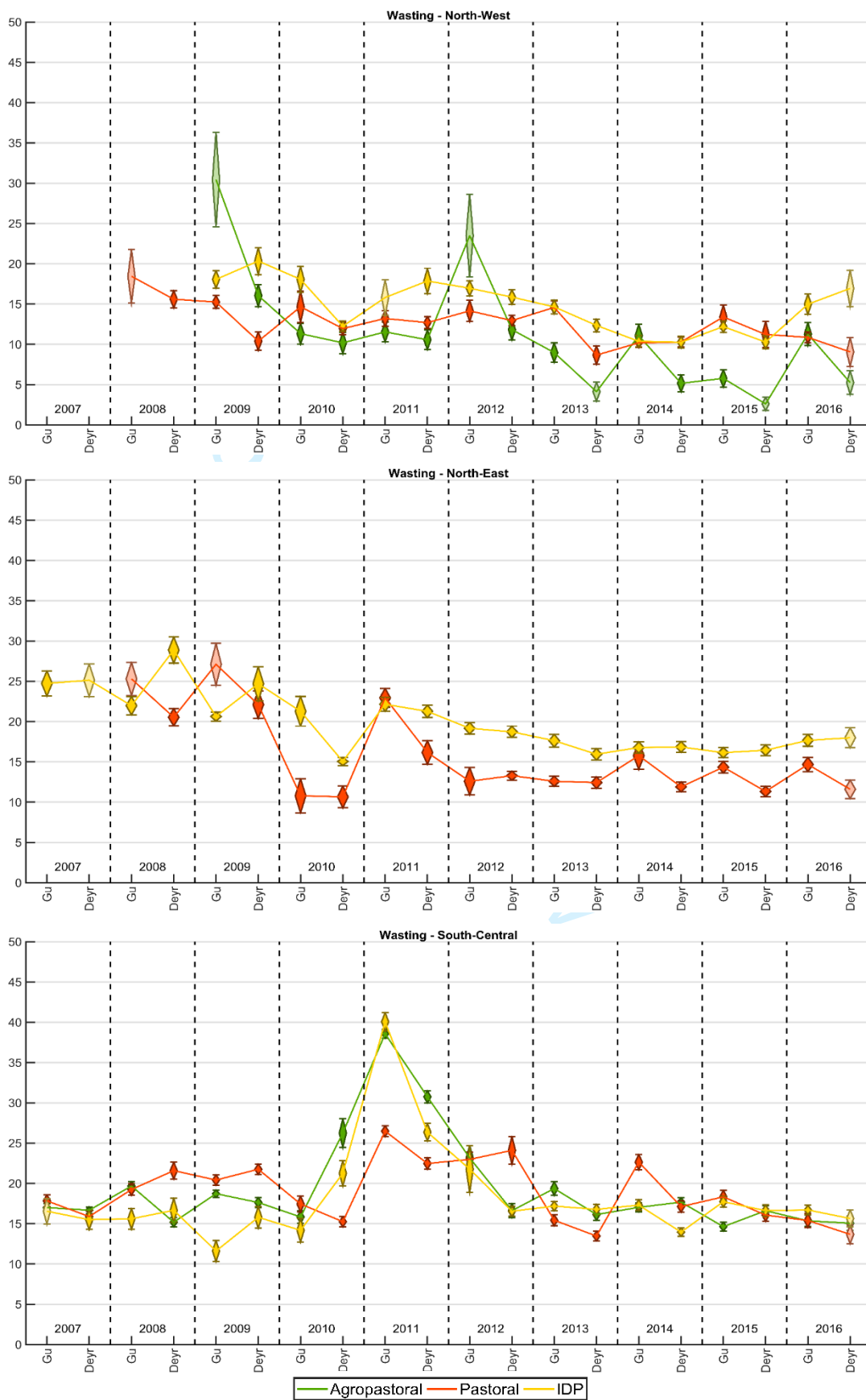
667 **Figure 3.** Growth patterns cohorts of children 6-59 months in agro-pastoralists and
668 pastoralists populations in the South Central zone of Somalia

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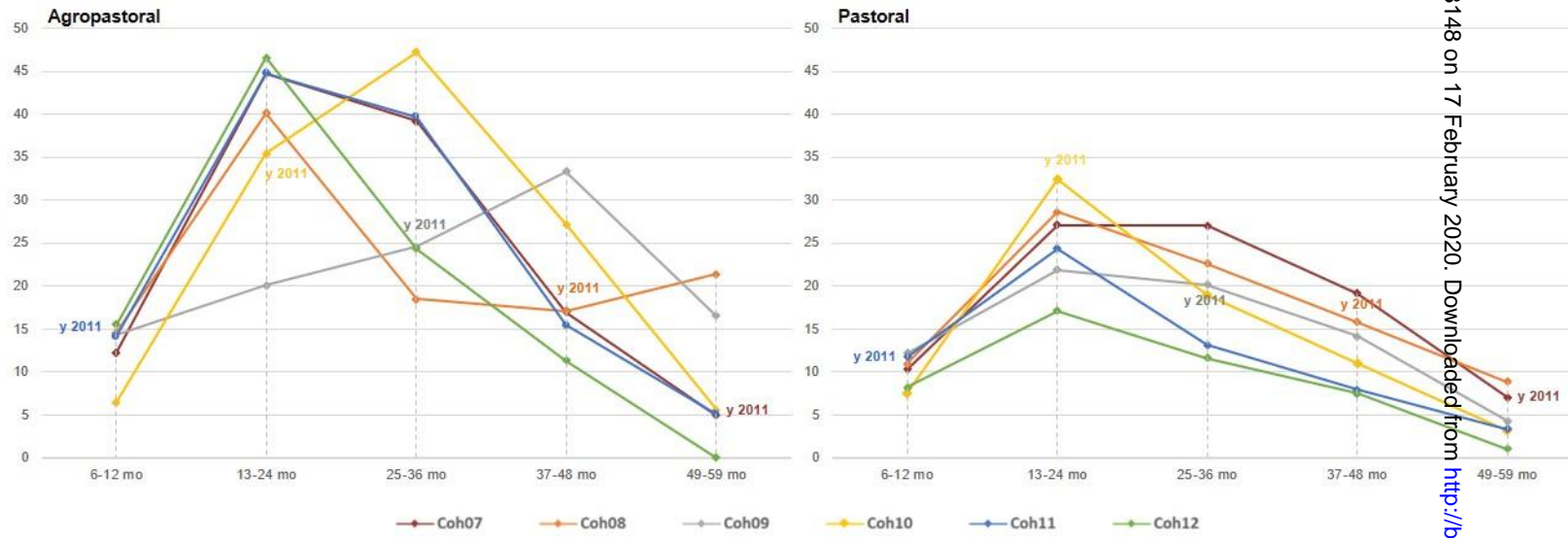
671 **Figure 4:** Morbidity estimates and confidence intervals at 95% (diamond shapes) by year
672 and season of analysis for each livelihood and disaggregated in the three operational
673 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
674 imputed.

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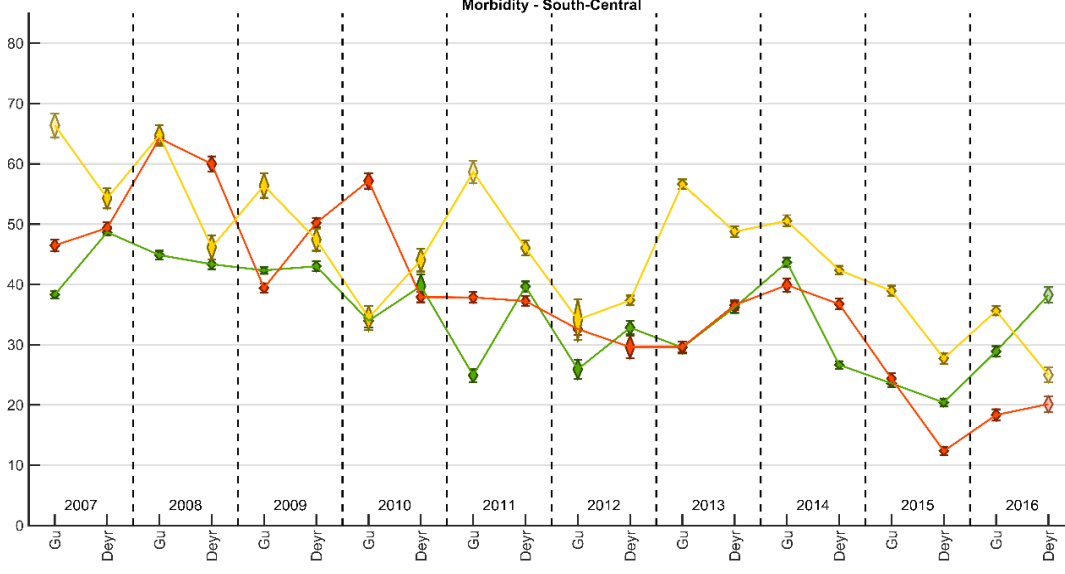
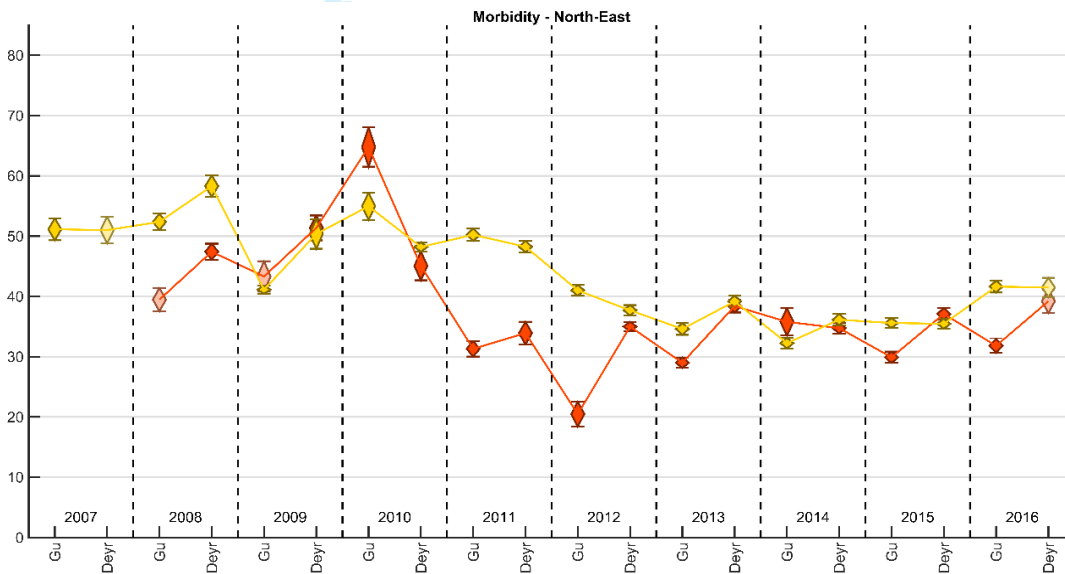
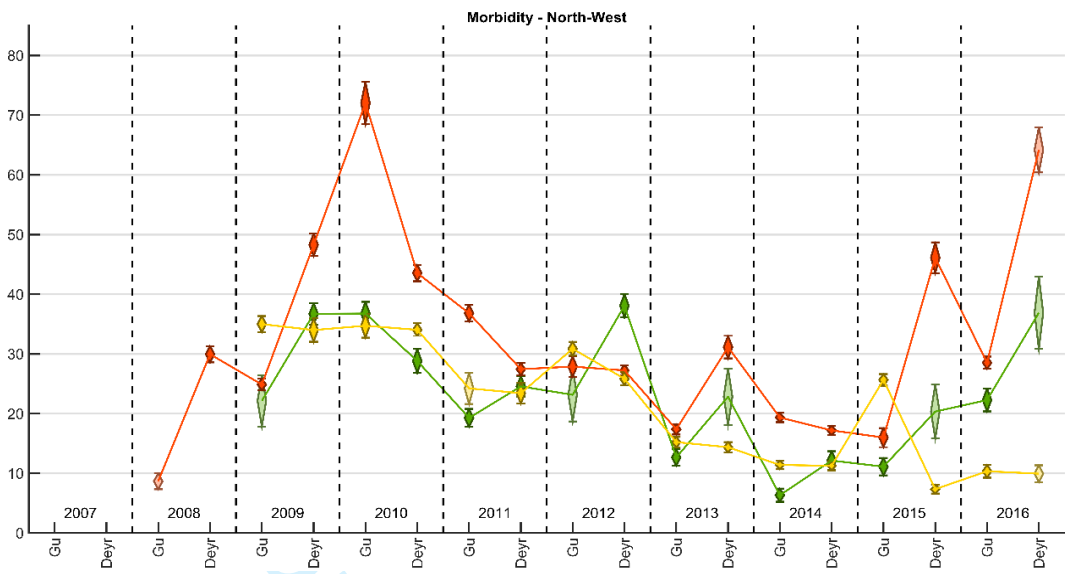




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— Agropastoral — Pastoral — IDP

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Annex 1. Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu			
North West																				49585
Agropastoral						716	609	520	684	643		617	568		496	445	467		488	6253
Pastoral				1128	2045	702	334	1781	1203	1937	692	2594	1892	611	2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				69275
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2083	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658	2913	3210	3393	3222	2574	45987
South Central																				163654
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,753	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,199	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,411	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16433	17873	23204	18694	15888	16312	282514

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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 & 10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10
		(b) Describe any methods used to examine subgroups and interactions	10
	(c) Explain how missing data were addressed	9	
	(d) If applicable, describe analytical methods taking account of sampling strategy	8-9	
	(e) Describe any sensitivity analyses	n.a.	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	n.a.
		(c) Consider use of a flow diagram	n.a.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	12-18
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-19 and 31

		(b) Report category boundaries when continuous variables were categorized	12-18
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19-23
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-23
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from 291 cross-sectional surveys

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2019-033148.R2
Article Type:	Original research
Date Submitted by the Author:	24-Dec-2019
Complete List of Authors:	Martin-Canavate, Rocio; European Commission Joint Research Centre Custodio, Estefania ; European Commission Joint Research Centre, Yusuf, Abukar; Food and Agriculture Organization of the United Nations, Food Security and Analysis Unit Molla, Daniel; Food and Agriculture Organization of the United Nations, Food Security and Nutrition Analysis Unit Fasbender, Dominique; European Commission Joint Research Centre Kayitakire, Francois; European Commission Joint Research Centre
Primary Subject Heading:	Global health
Secondary Subject Heading:	Emergency medicine, Nutrition and metabolism
Keywords:	wasting, stunting, morbidity, Somalia

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3 1 **Malnutrition and morbidity trends in Somalia between 2007 and 2016: results from**
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5 2 **291 cross-sectional surveys**
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20 7 §The first two authors have contributed equally to the manuscript.
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21 **ABSTRACT**

22 **Background:** More than two decades of conflict and natural disasters in Somalia have
23 resulted in one of the longest running humanitarian crises in the world. Nutrition data has
24 been collected over the years despite challenges to inform programmatic action. This
25 paper explores malnutrition and morbidity trends in Somalia during the last decade,
26 disaggregated by geographical zone and livelihood system.

27 **Methods:** We used data from 291 cross-sectional surveys conducted in children aged 6-
28 59 months between 2007 and 2016 in Somalia. Wasting, morbidity and stunting
29 prevalences over time were analysed by geographic area, livelihood system and season.
30 Logistic regressions were used to test trends.

31 **Results:** The wasting trends show a striking peak in 2011, more marked in southern and
32 central Somalia (SCZ) and coinciding with the famine declaration. The trend declines
33 slightly thereafter although not consistently across all zones and livelihoods, and it raises
34 again in 2016 especially among Internally Displaced Persons (IDPs). Stunting declined for
35 all groups and in all zones, but with more consistent patterns in northern Somalia.
36 Morbidity also showed a declining trend, although with multiple peaks depicting disease
37 outbreaks.

38 Pastoralist showed the lowest stunting estimates overall, while agrarian populations
39 showed the lowest prevalence of wasting and morbidity. IDPs were the most affected by
40 all outcomes. Seasonality affected the three outcomes differently by livelihood system.
41 Stunting rates increased after the 2011 famine for all age groups within children under five
42 years.

43 **Conclusions:** Despite the continuous complex situation in Somalia, there has been a
44 sustained decline in stunting and morbidity in the last decade. Wasting trends have

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3 45 remained at very high levels especially in north-east and the south zones of Somalia. The
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5 46 findings support the importance of performing trend analyses disaggregated by zone and
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7 47 livelihood groups within countries, to better identify priorities for program intervention.
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12 13 14 49 **STRENGTHS AND LIMITATIONS OF THIS STUDY**

- 15
16 50 • The sample characteristics in terms of size and number of surveys allowed for a
17
18 51 high precision in the analysis and for the stratification by livelihood systems,
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20 52 although the so called IDPs livelihood was over-represented
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22 53 • The data collected at village level was aggregated at the operational zone level and
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24 54 stratified by livelihood systems providing a broad perspective relevant for policy
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26 55 analysis and programming
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28 56 • Data were collected in field conditions, which may have an impact on the accuracy
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30 57 of measurements, although survey teams were consistently trained and equipment
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32 58 precision regularly monitored to avoid it.
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34 59 • Accurate age estimation was problematic as there were no accurate records of birth
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36 60 and age determination mostly relied on maternal recall.
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38 61 • Data quality validation was carried out daily by running the ENA plausibility checks
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40 62 and after each data collection data vetting was conducted by the Assessment and
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42 63 Information Management Working Group in Somalia.
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65 **BACKGROUND**

66 Somalia has been experiencing a long humanitarian crisis for the past two decades. It has
67 suffered protracted war and conflict, political instability, disruption of economy and
68 humanitarian assistance, and extreme climatic conditions since collapse of state
69 institutions in 1991, resulting in large-scale food and nutrition security crises. In 2011 the
70 country suffered a famine, more than 250,000 people are estimated to have died of
71 starvation and approximately 53% of the population experienced food crisis. An estimated
72 200,000 people had also died during a previous famine in 1991/1992 (1).

73 On top of the two mentioned famines, the rates of acute malnutrition have remained at
74 very high levels since the start of the conflict, and they are among the highest in the world
75 today. The causes of different forms of malnutrition in Somalia are multi-factorial and
76 linked not only to food insecurity but also to morbidity and inadequate caring practices, all
77 of them related to the disruption of peoples livelihood, destitution, large-scale population
78 displacement and the limited access to basic services (2) (3) (4).

79 Nutrition response programming has been taking place in Somalia for decades, in the form
80 of live-saving interventions like distribution of food and cash, treatment of acute
81 malnutrition, targeted supplementary feeding, and emergency public health measures
82 during disease outbreaks, as well as in the form of livelihoods recovery and development
83 programmes in agriculture, livestock, water, and environment in order to improve resilience
84 among vulnerable populations (5). However, effectiveness of humanitarian assistance
85 continues to be constrained by prevailing insecurity which restricts access and delivery of
86 aid to some areas.

87 The Food Security and Nutritional Analysis Unit (FSNAU) is an FAO project with the
88 mission to conduct national nutrition surveillance in Somalia since the year 2000 in order

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3 89 to monitor the nutritional status of the population and inform program interventions.
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5 90 FSNAU has been collecting data through different surveillance systems including nutrition
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8 91 surveys, rapid Mid-Upper Arm Circumference (MUAC) assessments, passive health
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10 92 facility-based screening and, at some times and places, by sentinel site surveillance.
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13 93 In 2009 FSNAU carried out a meta-analysis study including a systematic review of findings
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15 94 and raw data analysis of surveys conducted by FSNAU and partners in Somalia for the
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18 95 period 2001-2008 focusing on wasting trends and casual factors (6). In addition, in 2012
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20 96 WFP released a report analysing trends of food and nutrition insecurity in Somalia for the
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23 97 period 2007-2012 (7). Since then, no other systematic review of the nutrition data collected
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25 98 by FSNAU has been published.
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28 99 The reports circulated by FSNAU in the 2007-2016 period have been exhaustive in
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31 100 describing the nutrition situation in regular periods (monthly, bimonthly, quarterly or twice
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33 101 yearly depending on the year) and by livelihood zone. They combine results from different
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35 102 data collection methods to assess the overall nutrition situation, as well as to identify
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38 103 malnutrition hotspots and to closely follow-up specific population groups such as internally
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40 104 displaced populations (IDP) or particular livelihood zones (8). However, these data and
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42 105 results are not compiled and disseminated within the global nutrition reports due to having
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45 106 results aggregated at the livelihood zone level and not by any type of administrative
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47 107 divisions.
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50 108 The three operational zones of Somalia have been affected differently by the conflict,
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53 109 being the South-central zone (SCZ) historically the most affected one, whereas the North
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55 110 West (NWZ) and the North East zones (NEZ) have been generally more stable, with better
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57 111 governance and institutional capacities. To show the malnutrition outcomes aggregated by
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112 operational zone adds to the results provided by FSNAU reports and allows for interpreting
113 the trends within each zone historical context.

114 On the other hand, the three main livelihood systems present in Somalia are unevenly
115 distributed across the country. Pastoralists are mainly distributed in the north west, east
116 and central parts, while agro-pastoralists and riverine livelihood systems mostly in the
117 South. (9). The prevailing insecurity has also triggered large-scale displacement of
118 populations, and settlements of internally displaced populations (IDPs) are found all over
119 Somalia, but in the SCZ predominantly. According to the latest United Nations High
120 Commissioner for Refugees (UNHCR) Forced Displacement report, among the 1.5 million
121 IDPs estimated in 2016, 893,000 were located in the SCZ (10). Showing malnutrition
122 outcomes and trends by type of livelihood is highly relevant, as the coping strategies to
123 prevent and overcome malnutrition differ depending on the livelihoods and/or displacement
124 situation of populations

125 Finally, food security and nutrition outcomes are importantly affected by seasonality in
126 Somalia as well, with annual crop and livestock production dependent on the two main
127 rainy seasons (*Gu* and *Deyr*). Seasonality impacts the general availability of food and the
128 rates of infection, among other things. Thus, understanding the typical seasonal
129 fluctuations is useful for predicting changes in malnutrition and morbidity rates (11).

130 Assessing the fluctuations in malnutrition by season within the year, over time year-to-
131 year, and differentiated by livelihood group is essential to facilitate interpretation of the
132 situation and target effective interventions, as shown by a similar exercise conducted in
133 the Greater Horn of Africa region (12).

134 The aim of this study is to explore and interpret observed trends in malnutrition (wasting
135 and stunting) and morbidity by operational zone, livelihood system and season of analysis

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3 136 for the 2007-2016 period, giving special attention to the effects of the 2011 famine on the
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5 137 malnutrition outcomes for the rest of the period.
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9 138 **METHODS**

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12 139 The data used for this study were obtained from 291 surveys undertaken by FSNAU and
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14 140 partners working in Somalia. All surveys included in this study had similar design (two
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16 141 stage cross-sectional surveys) and comparable probability sampling methods. They were
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18
19 142 carried out biannually in the *Gu* and in the *Deyr* seasons, from year 2007 to 2016.
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22 143 There are four main seasons defined by rainfall patterns in Somalia: the *Gu*, the main rainy
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24 144 season (April to June), the *Hagaa*, a short and cool dry season (July to September), the
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26 145 *Deyr*, the short rainy season (October to December), and the long and hot dry season
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29 146 called the *Jilal* (January to March) (13). Only surveys conducted in the *Gu* or in the *Deyr*
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31 147 seasons were taken into account for the analysis, as data collected in *Hagaa* or *Jilal*
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33 148 seasons was only available for years 2007 and 2009. Although the *Gu* and the *Deyr*
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35 149 seasons are both rainy seasons they represent different times of the year and have
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38 150 specific characteristics impacting food and security outcomes, as the *Gu* is preceded by
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40 151 the long hot dry season whereas the *Deyr* follows a short and cool dry one.
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43 152 Somalia has been divided into three main UN operational zones: Northwest, Northeast and
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45 153 South-Central, with varied social, livelihood and economic structures. These zones
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48 154 generally correspond to current administrative and political designations known,
49
50 155 respectively, as Somaliland, Puntland and other Federal Member States of the Federal
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52 156 Government of Somalia. The North West zone comprising the pre-war regions of Woqooyi
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54 157 Galbeed, Awdal, Togdheer, Sool and Sanaag regions; the North East zone that includes
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57 158 the pre-war regions of Bari and Nugal and the South Central zone comprising Mudug,
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3 159 Galgadud, Hiran, Bakool, Bay, Middle and Lower Shabelle, Middle and Lower Juba, Gedo
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5 160 and Banadir regions.

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161 The three main livelihoods in the country are broadly defined by common characteristics of
162 the household's economy: pastoralists rear livestock and are nomadic; agro-pastoralists
163 practise mixed crop and livestock production; and riverine live in the South Central
164 irrigated zones along the Shabelle and Juba rivers and are mainly agrarian (13).

165 Agropastoralists and riverine livelihoods are classified as *Agropastoral* in this analysis as
166 both are mainly sedentary and share similar characteristics in terms of their primary
167 dependence on crop cultivation as opposed to reliance on rearing livestock. Because of
168 the presence of a significant proportion of internally displaced population in the country,
169 FSNAU also collects data on IDPs. Surveys of main IDP settlements were included, and
170 these were coded as a further livelihood category, although it does not constitute a
171 livelihood system in *sensu stricto*. The FSNAU also collects data on selected urban
172 populations (mostly Kismayo and Mogadishu), but not as comprehensively and
173 consistently as on rural and IDP populations, thus we did not include them in this analysis.

174 Since 2007 and for both technical and operational purposes, FSNAU has conducted rural
175 livelihood-based surveys as opposed to administrative boundary-based surveys. A
176 livelihood zone map of Somalia was created based on climate, topography, natural
177 resources and local livelihood patterns, resulting into 32 rural livelihood zones. In 2015, the
178 32 rural livelihood zones were consolidated into 18, reasonably homogenous rural
179 livelihood zones. Detailed maps can be found at
180 <http://www.fsnau.org/products/maps/livelihood-maps> (14).

181 The surveys were conducted at livelihood zone level or main IDP settlement based on
182 multi-stage cluster sampling with probability proportional to size (PPS) design covering all
183 livelihood zones that were accessible at the time of the survey. The primary sampling units

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184 were the villages (clusters) which were selected randomly from a list of all the villages in
185 each livelihood zone, and the second unit of analysis were the households within the
186 sample villages, which were randomly selected using the Standardized Methodology for
187 Survey in Relief and Transition (SMART). All children aged 6 to 59 months living in the
188 selected household were measured and the child section of the survey questionnaire
189 administered to the child caregiver or household head. Households and villages were
190 assumed to follow the livelihood of the livelihood zone in which they were located. Sample
191 selection and sizes of the surveys (number of households and number of children) were
192 calculated using the Emergency Nutrition Assessment (ENA) software (Version 2011, July
193 9, 2015). Previous estimations of wasting measured by weight-for-height and crude
194 mortality rates for the surveyed areas were used for the sample size calculations,
195 separately for anthropometry and mortality. The higher of these two sample sizes was
196 used to determine the final sample size as the surveys integrate both anthropometry and
197 mortality. An additional 2-3% was added to the sample size to allow for dropout or refusal
198 to participate

199 In order to show results at the operational zone level we had to aggregate the data
200 collected at the livelihood zone level and allocate them to the corresponding operational
201 zone based on its location. However, as there are livelihood zones that geographically
202 cross the three operational zones taken into account for this analysis (like Coastal Deeh
203 crossing the SCZ and the NEZ or Hawd Pastoral crossing the SCZ and the NWZ, see
204 maps in <http://www.fsnao.org/products/maps/livelihood-maps>), we went down to the
205 clusters level in order to allocate children surveyed to the corresponding operational zone
206 according to the cluster (village) geographical location. In each zone, surveys were
207 aggregated according to the livelihood system of the livelihood zone they represented
208 (example, West Golis Pastoral and Guban Pastoral livelihood zones in the NWZ would be

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3 209 aggregated in the Pastoral sub-sample of the NWZ, according to 2014 livelihood zone
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5 210 distribution).

8 211 Although in most of the time points (season/year) of the study period we had
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10 212 representative data for each livelihood, due to field work restrictions in some specific
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12 213 season/years not all livelihoods systems were covered. Therefore, and in order to
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14 214 construct the trends for the whole period of analysis the missing values in-between the
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16 215 trend were imputed. The imputation method we used was logistic regression to calculate
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18 216 the predictions and the residuals. Missing values in the beginning of the trend (year 2007
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20 217 and 2008) were not imputed. Out of 159 time points analysed, only 24 estimations were
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22 218 imputed. Supplementary Table 1 in Annex 1 presents the compiled sample sizes of the
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24 219 population analysed in each time point, disaggregated by livelihood and zone.
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30 220 Data was collected by FSNAU survey enumerators, who are recruited locally from health
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32 221 centers, clinics etc. and are trained for five days before every survey as part of FSNAU's
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34 222 quality assurance process. As FSNAU nutrition surveys are conducted regularly (i.e. every
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36 223 season), only the best performing enumerators and supervisors are retained but they still
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38 224 have to undergo the mandatory five-day training before conducting each survey. FSNAU
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40 225 surveys are coordinated by FSNAU Nutrition Field Analysts and technical experts from the
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42 226 Ministries of Health, and data quality is validated in a daily basis by running the ENA
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44 227 plausibility checks. At the end of data collection there is a technical vetting conducted by
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46 228 the Assessment and Information Management Working Group established under the
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48 229 Somalia Nutrition Cluster for data coordination and quality control of nutrition surveys.
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53 230 The data were cleaned by deleting the records of individual children with any of the
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55 231 following criteria: age < 6 months (n=5), age > 59 months (n=6), and missing age
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57 232 (n=1137), sex (n=1222), weight (n=1134), height (n=1143) or oedema (n=1802). Weight-
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59 233 for-height z-score (WHZ) and length/height-for-age z-score (HAZ) were calculated using

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World Health Organization (WHO) Anthro (version 3.2.2, January 2011) and Macros using WHO 2006 growth standards. Extreme biologically implausible values were excluded based on WHO standards with recommended flag limits of WHZ scores below -5 or above +5 (n=545) and HAZ scores below -6 or above +6 (n=824)(15).

Nutritional status indicators used were *wasting* defined as weight-for-height below -2 Z-scores and/or the presence of nutritional oedema; and *stunting* or chronic malnutrition defined as height-for-age below -2 Z-scores (16). *Severe wasting* is defined as WHZ below -3 and/or the presence of nutritional oedema, thus severe wasting is included in the wasting definition. We provide the severe wasting estimates independently in Table 1 but the rest of the tables and figures only report wasting which includes both moderate and severe forms.

Child morbidity was assessed based on a 2-week recall of the incidence of diarrhoea, acute respiratory infection (ARI) and febrile illness and 30-days recall for suspected measles. A new variable called morbidity was created and coded as 1 if the child had a positive response to at least one of the four illnesses and as 0 if the child had a negative response to all of the four illnesses. We calculated the prevalence of wasting, morbidity and stunting for each of the surveys separately and provided the levels of uncertainty in the estimates with the 95% confidence intervals (CI).

We graphed the estimations and confidence intervals of wasting, stunting and morbidity for each year and season disaggregated by livelihood group and geographical zone for the patterns comparison over the 10-year time period.

In order to analyse the observed trends, we created two differentiated time periods, one before the famine of 2011 (including data from 2007 to 2010), and another one covering the time period after the famine (2012-2016). Logistic regressions were used to test the

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3 258 change of the nutrition and health outcomes with each additional year in each of the two
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5 259 periods, and to model the association of the outcomes with the *Gu* and *Deyr* seasons for
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8 260 the overall period. All analyses were stratified by livelihood system and geographical zone.
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10 261 Odd ratios (ORs) and confidence intervals (CI) were calculated.
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13 262 To explore the potential impact of the wasting peaks recorded during the 2011 famine on
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15 263 the subsequent stunting estimations, we created six artificial cohorts based on the
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17 264 children's year of birth. We constructed the cohort of 2007 (Cohort07) by selecting children
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20 265 who were 6-12 months in the year 2007, children that were 13-24 months in 2008, 25-36
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22 266 months in 2009, 37-48 months in 2010 and 49-59 months in 2011. The 2008 cohort
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24 267 (Cohort08) was constructed by selecting children that were 6-12 months in the year 2008,
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27 268 13-24 months in 2009, 25-36 months in 2010, 37-48 months in 2011 and 49-59 months in
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29 269 2012. Following the corresponding procedure, we constructed the rest of the cohorts for
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31 270 the years 2009 (Cohort09), 2010 (Cohort10), 2011 (Cohort11) and 2012 (Cohort12), and
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34 271 we graphed the prevalence of stunting (y-axis) for each cohort according to the age of the
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36 272 child (x-axis), highlighting the position of the 2011 famine in order to facilitate the
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38 273 interpretation of results. Due to data availability this analysis was restricted to the
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41 274 agropastoral and pastoralists populations of the South Central zone.
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43 275 Stata 15 (StataCorp, College Station, Texas, USA) was used for statistical analysis.
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46 276 Public and patient involvement

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49 277 Not patients were involved in the study. Results of the nutrition and mortality surveys
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51 278 conducted in Somalia are used for programmatic actions targeting the study participants
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54 279 (children under 5 years of age), but due to the characteristics of the study population there
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56 280 is no specific action planned to disseminate results directly to them.
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3 281 Access to survey sites was agreed with local authorities and community leaders in the
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5 282 districts where the clusters were sampled. Verbal consent for all caregivers of the sampled
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7 283 children was sought before administration of the questionnaire. Children who were found
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10 284 as severely malnourished or with any other medical problem during the survey were
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12 285 referred to the nearest health facility for medical attention and appropriate treatment using
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15 286 referral form.

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18 287 Ethical approval was provided through permission by the Ministry of Health (MOH)
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20 288 Somalia, Transitional Federal Government of Somalia Republic, Ref:
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22 289 MOH/WC/XA/146./07, dated 02/02/07. Subsequent survey plans and protocols were
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25 290 presented and discussed with MOH and partners prior to the conduct of each seasonal
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27 291 assessment.

30 292 **RESULTS**

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32
33 293 A total of 282 514 measurements of children aged 6 to 59 months from 291 surveys were
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35 294 examined from 2007 to 2016. The North West and North East zones of the country were
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37 295 mainly composed of pastoral livelihood zones with a large proportion of IDPs. The South
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40 296 Central zone, in addition to pastoralists and IDPs, also included agro-pastoral and riverine
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42 297 livelihoods (See Table 1).

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45 298 Of the children surveyed, 69 275 (24%) children were located in the North East zone, 49
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47 299 585 (18%) in the North East zone and 163 654 (58%) in the South Central zone of Somalia
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50 300 Supplementary Table 1 in the Annex 2 summarizes the survey data by zone, season and
51
52 301 period of analysis. The assessments were equally distributed in relation to the *Gu* (50.7%)
53
54 302 and the *Deyr* (49.3%) seasons. Around 36% of the children were surveyed before the
55
56 303 2011 year of famine, and 64% after year 2011.

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59 304 In Table 1 are summarized the children's characteristics by zone.
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Table 1. Characteristics of children 6 to 59 months in Somalia (n=282 514)

	North West (n=49 585) 17.5%	North East (n=69 275) 24.5%	South Central (n=163 654) 57.9%
Sex			
Male	50.9	50.6	50.8
Female	49.1	49.4	49.2
Age			
<24 months	35.7	34.9	35.8
≥24 months	64.3	65.1	64.2
Wasting			
Weight-for-height <-2 z-scores	12.7	17.0	19.3
Severe wasting			
Weight-for-height <-3 z-scores	2.5	4.0	5.7
Stunting			
Height-for-age <-2 z-scores	7.3	22.1	23.8
Morbidity	24.4	39.2	39.5
Diarrhoea	11.3	14.6	16.4
Acute respiratory infection	8.4	14.1	16.0
Febrile illness	12.9	25.7	22.7
Measles	2.5	4.1	3.9
Morbidity overall ¹	24.4	39.2	39.5
Livelihood system			
Agro-pastoralists	12.6	-	26.2
Pastoralists	46.6	33.6	30.7
Riverine	-	-	20.0
Internally displaced persons	40.8	66.4	23.1

¹Morbidity variable integrating the diseases described in the table. See Methods section for details.

Trends in wasting

The mean prevalence of wasting for the overall period of study was 13%, 17% and 19 % for the NWZ, NEZ and SCZ respectively.

Figure 1 shows in the first graph, for the NWZ, a steady decline in wasting estimates for all livelihoods and periods of analysis. Agropastorals' estimates declined to around 5% at the end the period, although with a steep increase above 10% in *Gu* 2016. Wasting among IDPs also increased sharply in 2016 in this particular zone.

In the NEZ, there was an important decrease in wasting estimates for each additional year until 2010 (OR=0.75 and OR=0.80 for pastorals and IDPs respectively) see Table 2,

315 although estimates raised at above 20% in 2011. Since 2012 wasting prevalence has
 316 remained above 10% among pastoralists and above 15% among IDPs (second graph of
 317 Figure 1).

318 The third graph of Figure 1 shows the wasting estimates for the SCZ above 15% for the
 319 three livelihoods in most of the years, and the peak of wasting prevalence above 35% in
 320 year 2011 for agropastorals and IDPs. This peak was less pronounced among pastoralists,
 321 although it was sustained longer in time. In the second period of analysis, starting in 2012,
 322 there was a slight decrease on wasting for each additional year (see Table 2).

323 In all zones, wasting was higher during the *Gu* seasonal analysis for all livelihoods,
 324 although the difference was more marked for pastoralists and IDPs.

Table 2. Trend analysis on wasting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.59 (0.42-0.84)	0.87 (0.78-0.97)	1.10 (1.0-1.5)
2012-2016	0.90 (0.81-1.01)	0.91 (0.87-0.95)	0.98 (0.95-1.0)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.06 (0.88-1.26)	1.15 (1.06-1.24)	1.23 (1.16-1.29)
North East Zone			
Trend per year			
2007-2010		0.75 (0.66-0.86)	0.80 (0.75-0.84)
2012-2016		1.00 (0.96-1.03)	0.96 (0.94-0.99)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	1.26 (1.16-1.36)	0.96 (0.95-0.97)
South Central Zone			
Trend per year			
2007-2010	1.03 (1.0-1.06)	1.00 (0.98-1.04)	1.07 (1.00-1.15)
2012-2016	0.93 (0.91-0.96)	0.94 (0.92-0.97)	0.98 (0.95-1.00)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.07 (1.01-1.13)	1.15 (1.1-1.2)	1.23 (1.17-1.30)

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3 326 **Trends in stunting**

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5 327 For the first period of analysis (2007-2010) the stunting estimates have decreased
6
7 328 significantly for each additional year in the three zones and all livelihoods (See Figure 2
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9
10 329 and Table 3) although in the NWZ there was a peak for pastoralists observed in Gu 2010,
11
12 330 and for all livelihoods in Deyr 2008 in the other two zones (NEZ and SCZ).

13

14

15 331 During the second period of analysis, there was a small peak of stunting in year 2012 in
16
17 332 the NWZ for all livelihoods but ever since estimates have been declining steadily in this
18
19 333 zone, reaching estimates below 5% at the end of the period. In the NEZ the peak was
20
21
22 334 observed for all livelihoods at the end of 2011 and early 2012, with a subsequent decrease
23
24 335 thereafter reaching a prevalence around 5% for pastoralists and 15% among IDPs (Figure
25
26 336 2). The stunting estimates among pastoralists are approximately a third of the IDPs in this
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28
29 337 zone during the whole period of analysis.

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32 338 Stunting trends in the SCZ increased sharply in 2011, and then again in 2013 for
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34 339 agropastorals and IDPs only. After that rates decreased to below 5% for pastoralists,
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36 340 below 10% for agropastorals and only slightly, to around 25% for IDPs in 2016.
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38 341 Pastoralists show the lower stunting rates overall.

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41 342 Stunting rates were consistently higher in the *Gu* season except for the NEZ pattern.

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Table 3. Trend analysis on stunting per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.53 (0.37-0.78)	0.79 (0.72-0.88)	0.33 (0.27-0.40)
2012-2016	0.92 (0.77-1.10)	0.82 (0.77-0.88)	0.86 (0.81-0.91)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	1.32 (0.1-1.64)	1.15 (1.04-1.27)	1.90 (1.70-2.12)
North East Zone			
Trend per year			
2007-2010		0.59 (0.51-0.69)	0.84 (0.80-0.88)

	2012-2016		0.87 (0.83-0.91)	0.86 (0.84-0.88)
Season				
	Deyr (Oct.-Dec.)	-	Ref.	Ref.
	Gu (April-June)	-	0.89 (0.85-0.89)	0.96 (0.93-1.00)
<hr/>				
South Central Zone				
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Trend per year				
	2007-2010	0.88 (0.86-0.90)	0.92 (0.89-0.95)	0.65 (0.61-0.70)
	2012-2016	0.72 (0.70-0.74)	0.89 (0.86-0.92)	0.96 (0.94-0.98)
Season				
	Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
	Gu (April-June)	1.04 (1.00-1.10)	1.35 (1.29-1.41)	1.29 (1.23-1.36)

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3 345 Figure 3 represent the growth patterns based on height for age, showing the stunting rates
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5 346 by age group for the six self-constructed cohorts in the agro-pastoral and pastoral
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7 347 livelihoods of the SCZ (See Methods section for details). In both livelihoods and all
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9
10 348 cohorts, we observe a peak in stunting at 24 months of age, which declines thereafter in
11
12 349 most of the cohorts. Exceptions to this pattern are, among the agro-pastoralists, the
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14 350 Coh2009 and the Coh2010 which experience an increase in stunting prevalence after the
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16
17 351 initial peak at 24 months, and the Coh2008 which despite initial decline after the 24
18
19 352 months' peak, experiences a later increase among the children 49-59 months of age.
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21 353 Among the pastoralists exceptions to the observed pattern were the Coh07 and the Coh09
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24 354 for which the stunting prevalence increased or decreased only slightly respectively after
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26 355 the first 24 months' peak.
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29 356 The cohort of children born in 2012 (Coh12) showed the growth patterns with sharper
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31 357 declines in stunting prevalence after initial peak at 13-24 months of age and throughout all
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34 358 the older age groups.

36 359 **Trends in morbidity**

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40 360 The mean prevalence of reported morbidity for the overall period of analysis was 24.4% in
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42 361 the NWZ, 39.2% in the NEZ and 39.5% in the SCZ.

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45 362 In Figure 4 we observe the jagged patterns of morbidity estimations, with peaks over 50%
46
47 363 in several time points (season/year) for the pastoralists and IDP populations.

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49
50 364 Pastoralists showed in the NWZ a significant increase in morbidity for each additional year
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52 365 until 2010 (Table 4) and two important peaks in the *Deyr* seasons of 2015 and 2016, while
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55 366 in the NEZ values for pastoralists have been steadily between 30 and 40% since *Deyr*
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57 367 2012. In the SCZ, however, there was a significant decrease of morbidity during the whole
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59 368 period of analysis for pastoralists, more marked during the second period (0.8 decrease
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per each additional year, see Table 4), although with a steep rise at the end of the period, in year 2016.

Agropastorals on the other hand, showed a decreasing trend in the two periods and zones where they are present, although with a marked increase in year 2016 as well.

Among IDPS morbidity has been decreasing significantly since 2012 both in the North West and South Central zones but remaining stagnant at levels around 40% in the NEZ.

For agropastoral and pastoralists' populations morbidity was higher during the *Deyr* season, while for IDPs in the NWZ and SCZ it was higher during the *Gu* seasonal analysis.

Table 4. Trend analysis on morbidity per period of analysis and season

	Agropastoral	Pastoral	IDPs
North West Zone			
Trend per year			
2007-2010	0.70 (0.55-0.89)	1.5 (1.4-1.6)	1.00 (0.86-1.15)
2012-2016	0.90 (0.83-0.99)	1.0 (1.0-1.1)	0.77 (0.74-0.80)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.77 (0.67-0.88)	0.86 (0.81-0.91)	1.29 (1.20-1.38)
North East Zone			
Trend per year			
2007-2010		0.99 (0.89-1.1)	0.85 (0.81-0.89)
2012-2016		1.04 (1.01-1.06)	0.99 (0.97-1.00)
Season			
Deyr (Oct.-Dec.)	-	Ref.	Ref.
Gu (April-June)	-	0.79 (0.74-0.83)	0.94 (0.90-0.98)
South Central Zone			
Trend per year			
2007-2010	0.95 (0.93-0.97)	0.89 (0.87-0.92)	0.78 (0.74-0.82)
2012-2016	0.85 (0.83-0.87)	0.81 (0.78-0.83)	0.82 (0.80-0.83)
Season			
Deyr (Oct.-Dec.)	Ref.	Ref.	Ref.
Gu (April-June)	0.84 (0.80-0.87)	1.01 (0.98-1.05)	1.38 (1.32-1.44)

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DISCUSSION

To our knowledge, this is the first study analysing malnutrition and morbidity trends comprehensively during the period 2007-2016 in Somalia. We observe a decreasing trend in morbidity overall, although with multiple peaks depicting disease outbreaks. Stunting also declined for all groups and in all zones, but with more consistent patterns in the northern ones. The wasting trends show a striking peak in 2011, more marked in the SCZ and coinciding with the famine declaration. A slight decreasing trend is observed thereafter although not consistent across all zones and livelihoods, and with a raising slope in 2016, especially among IDPs.

Since early nineties, the food security and nutrition situation in Somalia has been characterised by protracted and recurrent emergency situations resulting from repeated episodes of drought, flooding, conflict and large-scale population displacement. The frequency and severity of these crises have been exacerbated by the absence of strong government and lack of humanitarian space (17). Conflict related violence and insecurity prevent the delivery of humanitarian aid, disrupts livelihoods and breaks down familial and community networks that can provide the necessary support and guidance needed for looking after young children, including their nutritional requirements (18) Food insecurity and conflict have been shown to have a direct and independent impact on malnutrition (19), but also infectious diseases are identified as main drivers of malnutrition in Somalia (20).

In relation to wasting, we observe the rising trend in 2009-2010 coinciding with the slow onset of drought driven by four consecutive rain failures, which together with some of the most violent conflict and restricted humanitarian access in Somalia's history contributed to the 2011 famine, reflected in our results with wasting peaks above 35% among IDPS and agro-pastoralists in the SCZ and above 20% among pastoralists and IDPS in the NEZ. The

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3 405 situation was further aggravated by the economic crisis, characterized by currency
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5 406 devaluation, disrupted trade and market activities, and hyperinflation of basic food and
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8 407 non-food items (21), and by al-Shabaab's blocking of humanitarian operations in areas
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10 408 under their control (22). It is estimated that nearly 260 000 people died during the 2011
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12 409 famine(23), half of them children.

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15 410 After the 2011 peak the wasting prevalence dropped from the extremely high levels
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18 411 registered in the SCZ and NEZ to around 15%, at the level it remained for the rest of the
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20 412 period, still a very high prevalence which flags the threshold for emergency according to
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22 413 the World Health Organization (24). The pronounced decrease was mainly the result of the
23
24 414 intense humanitarian actions but could also be reflecting the increased under five mortality
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27 415 in 2011, which affected severely acutely malnourished children primarily, and that peaked
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29 416 at 5.83 deaths per 10,000 in the South Central zone (25) (26). The SCZ was the most
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31 417 affected by the 2011 famine and shows the highest wasting levels for all livelihoods in the
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33
34 418 consequent years. This zone is impacted by higher intensity of conflict, flooding of the
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36 419 riverine areas, continued displacements, restrictions of movements and goods due to clan
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38 420 and religious insurgency, and low availability and poor quality of health services (27).
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41 421 Moreover, the IDPs show consistently the highest estimates of wasting in all zones. They
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43 422 are considered to be among the poorest population groups in the country and their
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45 423 vulnerability to malnutrition is highly linked to poor access to food, income, health care,
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48 424 and safe water coupled with high morbidity burden (28). In this group, our results show the
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50 425 raising trend in wasting in early 2016 which resulted in a declaration of high famine risk in
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52 426 early 2017 (29) previously mentioned. Stunting estimates are also consistently higher
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54 427 among IDPs, especially in the NEZ and the SCZ.

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58 428 These results are in line with the FSNAU annual technical reports when compared to
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60 429 specific years or populations groups (to be found at <http://www.fsnau.org>), as could not be

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3 430 otherwise, but adding the broad perspective of data aggregated at the operational zone
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5 431 level and by livelihood system thus helping to interpret the impact of policies already
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8 432 implemented and to better target future interventions based on operational zones and type
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10 433 of livelihood.

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13 434 The overall pattern of stunting is a declining trend for all livelihood groups in the three
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15 435 zones. This decline had been projected by policy reports and international tracking tools
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17 436 (30) (31) based on data collected in 2009. Our results shows the trends with data collected
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20 437 in the period 2007-2016 by operational zones and by livelihood systems which can help to
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22 438 better target the efforts needed to maintain a stunting declining trend as to reach the World
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24 439 Health Assembly targets by 2025.

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27 440 Pastoralists' children seem to be more resilient to stunting, with estimates consistently
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30 441 lower, reaching very low levels (below 5%) in all three zones at the end of the period.

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32 442 Other studies have suggested this is a result of the physical stature of Somali pastoralists
33
34 443 as tall and lean, which may mask the actual estimates of chronic malnutrition (32), but
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37 444 decreasing trends are clear nonetheless. Another potential explanation for this
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39 445 differentiation is that pastoral groups have relatively better asset base and access to
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41 446 animal products, especially milk and cow's blood, which provide high protein diets even
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44 447 when food is scarce. This type of diet, also rich in iron, calcium and other micronutrients
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46 448 will favour continued height growth rather than soft tissue. The opposite applies for
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48 449 agriculturalists as energy may be provided by cereals but protein and micronutrient intake
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50 450 may be compromised, favouring stunting but less wasting. The higher rates of malnutrition
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53 451 observed among pastoralists in the analysis after the *Gu* rains may be associated with the
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55 452 restricted access to their typical diet in the precedent *Jilal* season. During that extended
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57 453 dry season from mid-January to mid-April the pastoralists adult male and adolescent boys
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60 454 migrate with the livestock to distant grazing areas, leaving women and young children

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3 455 behind with limited access to milk and other animal source products (33). And this is
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6 456 consistent with findings from pastoralist populations of other countries in the region (12).
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8 457 Also the amount and intensity of the Gu rains tends to be high in the NWZ and SCZ which
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10 458 can lead to increased morbidity among IDPS due to increased contamination and
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12 459 infections. And although this may have a more clear impact on wasting as an indicator
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14 460 sensitive to short term changes, our results show the same seasonal fluctuations in
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17 461 stunting estimates, and recent studies are highlighting the role of seasonality as potential
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19 462 risk factor to poor growth among young infants (34).
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22 463 Also important to notice is the stunting peak consistently shown for all livelihoods in the
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24 464 immediate years after the famine, probably reflecting the effects in stunting of the
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26
27 465 extremely high rates of wasting.
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30 466 These same observations are replicated in the results of the agro-pastoralists and
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32 467 pastoralists artificial cohorts we created for the SCZ. The stunting rates are consistently
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34 468 lower and the stunting fluctuations consistently softer among the pastoralists' cohorts as
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37 469 compared to the agro-pastoral ones, and a relation is observed between the high wasting
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39 470 peak in 2011 and the stunting in the subsequent years.
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41
42 471 The overall growth pattern we observe in our cohorts, with stunting peaks within the 13-24
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44 472 months of age, is consistent with the growth faltering observed in other deprived
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46
47 473 populations of the world, which show a stunting crowning around 24 months of age which
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49 474 decreases thereafter (35). The interpretation of childhood catch-up after 24 months is that a
50
51 475 combination of the normal postnatal maturation of the children's immune systems and the
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54 476 development of a broad range of adaptive responses against previously encountered
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56 477 pathogens reduces the frequency and severity of growth-impairing infections (36). This is
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58 478 the observed pattern in most of the pastoralists' cohorts we created in the SCZ. However,
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60 479 among the agro-pastorals the only cohort that follows that clear pattern is the Coh2012,

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480 which encompasses the children born after the 2011 famine. In all the rest of the cohorts
481 the growth pattern changes, as the stunting prevalence experiences a sharp increase a
482 year after the children have experienced the 2011 famine, independently of the age of the
483 children during that period. This suggests a strong impact of the high wasting rates in the
484 subsequent stunting prevalence. This association has been shown in longitudinal studies
485 that have reported that children with wasting or negative changes in weight for height are
486 at greater risk of linear growth retardation (34) (37), and the differentiated patterns for
487 children among pastoralists and agropastoralists populations are consistent with similar
488 studies conducted in the region (12).

489 In relation to morbidity, although it declined during the period of analysis, prevalence were
490 still high, especially among IDPs. Pervasive morbidity is associated with limited access
491 and utilisation of basic health and water services and IDPs reside in temporary
492 infrastructures and crowded conditions, which exacerbate their vulnerability to infectious
493 diseases (38). Also, and for all the livelihood groups, the morbidity trends showed
494 numerous peaks reflecting disease outbreaks such as measles, polio, acute watery
495 diarrhoea and cholera almost every year since 2007. Somalia is one of the acute watery
496 diarrhoea/ cholera-endemic countries in the world and according to UNICEF, contains “the
497 largest known reservoir of unvaccinated children in a geographic area in the world”
498 (around half a million children). The rise in morbidity observed in 2016 corresponds with
499 the cholera and measles outbreaks occurring in that year (39) (40) which further contributed
500 to the rise in acute malnutrition and mortality which reached near-famine thresholds at the
501 start of 2017, only averted by the large-scale and sustained humanitarian actions (29).

502 As already shown by other studies, the provision of malnutrition and morbidity estimates,
503 when seen in the context of historical values and viewed as specific to different livelihood

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504 groups can provide useful timely warning of the need for intervention to mitigate
505 developing nutritional crises (12).

506 Limitations and strengths of the study

507 The sample characteristics in terms of size and number of surveys allowed for a high
508 precision in the analysis and for the stratification by livelihood system. However, despite
509 the enhanced precision of the estimates of malnutrition and morbidity showed by the
510 narrow confidence intervals, due to the effects of confounding and bias (measurement and
511 or recall bias) inherent in cross sectional and nutritional surveys, the analysis may produce
512 spuriously precise but biased estimates of association and stability.

513 The aggregation of the data at the operational level and by livelihood system permitted the
514 analysis from a different perspective and additional insights for policy makers. The so
515 called IDPs livelihood was over-represented in the overall population as recent data
516 indicated that the proportion of IDPs in Somalia population was around 14% (38), thus the
517 importance of the stratified analysis.

518 Although the data was collected at village level and could have the potential to derive the
519 impact of locality and environmental conditions on individual outcomes the geo-localization
520 of the clusters surveyed was challenging due to a lack of updated Somalia cartography
521 and changes in villages names and spelling over the years during the period of study.

522 Data were collected in field conditions, which may have an impact on the accuracy of
523 measurements, although the FSNAU survey enumerators' long-time experience and
524 routinely training may have minimized this limitation.

525 Imputed values have to be interpreted with caution as they can introduce a bias. However,
526 as shown in the figures the imputed values are randomly distributed in the years, zones

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3 527 and livelihood groups studied thus we do not consider they are impacting the trends
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5 528 patterns in a systematic way
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8 529 Accurate age estimation can be a major problem as there are no accurate records of birth
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10 in Somalia and age determination mostly relies on maternal recall. However, FSNAU
11 530 conducted the ENA plausibility checks on every survey to minimize any potential bias and
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13 531 the age distribution in the sample shows the expected distribution.
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18 533 Finally, the construction of artificial cohorts to assess the impact in growth retardation of
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20 534 the wasting peaks during the 2011 famine showed interesting results. We recommend to
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22 apply this methodology when longitudinal data is not existent but repeated cross-sectional
23 535 data are available for the population of study.
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26 27 28 537 **CONCLUSIONS** 29 30

31 538 The international community has been implementing humanitarian, recovery and
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33 539 development programmes for the Somali population in a complex and varied environment
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35 for the last decade, with ambivalent results.
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39 541 Although wasting and morbidity prevalence remained high during the period of analysis
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41 542 there was a slight but clear decreasing trend for both indicators, only reversed at the end
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43 543 of the period, 2016, when severe drought conditions impacted most parts of the country.
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45 544 Furthermore, the decrease in stunting for the 2007-2016 period is remarkable.
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49 545 The association found between high wasting prevalence and subsequent high stunting
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51 546 estimates calls for a more holistic response which addresses humanitarian life-saving
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53 547 needs and development work simultaneously.
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56 548 Moreover the focus on reducing malnutrition in Somalia clearly needs to move away from
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58 549 the short-term response aimed at addressing acute food insecurity and treatment of
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60 550 acutely malnourished children to a more integrated response that includes access to clean

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551 water, the promotion of hygiene and sanitation, and the improvement of access to basic
552 health services among its priorities.

553 Finally, the households' vulnerability towards morbidity and malnutrition varies according to
554 the type of livelihoods they pursue. Significant improvements can only be realized taking
555 into account the specific challenges and opportunities within the various livelihoods across
556 Somalia.

557 **Authors' contributions**

558 RCM & EC were involved in all stages from the conception and design, data acquisition,
559 analysis and interpretation. FK and DF contributed to the study design, the data analysis
560 and interpretation. DM & AY were responsible for conducting the surveys and managing
561 the data. All authors have critically reviewed and approved the final version of the article.

562 **Competing interests**

563 The authors declare that they have no competing interests.

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566 **Availability of data and material**

567 The data that support the findings of this study are available from FSNAU but restrictions
568 apply to the availability of these data, which were used under license for the current study,
569 and so are not publicly available. Data are however available from the authors upon
570 reasonable request and with permission of FSNAU.

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572 Not applicable.

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3 684 **FIGURE'S LEGENDS**
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7 686 **Figure 1:** Wasting estimates and confidence intervals at 95% (diamond shapes) by year
8 687 and season of analysis for each livelihood and disaggregated in the three operational
9 688 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
10 689 imputed.
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14 691 **Figure 2.** Stunting estimates and confidence intervals at 95% (diamond shapes) by year
15 692 and season of analysis for each livelihood and disaggregated in the three operational
16 693 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
17 694 imputed.
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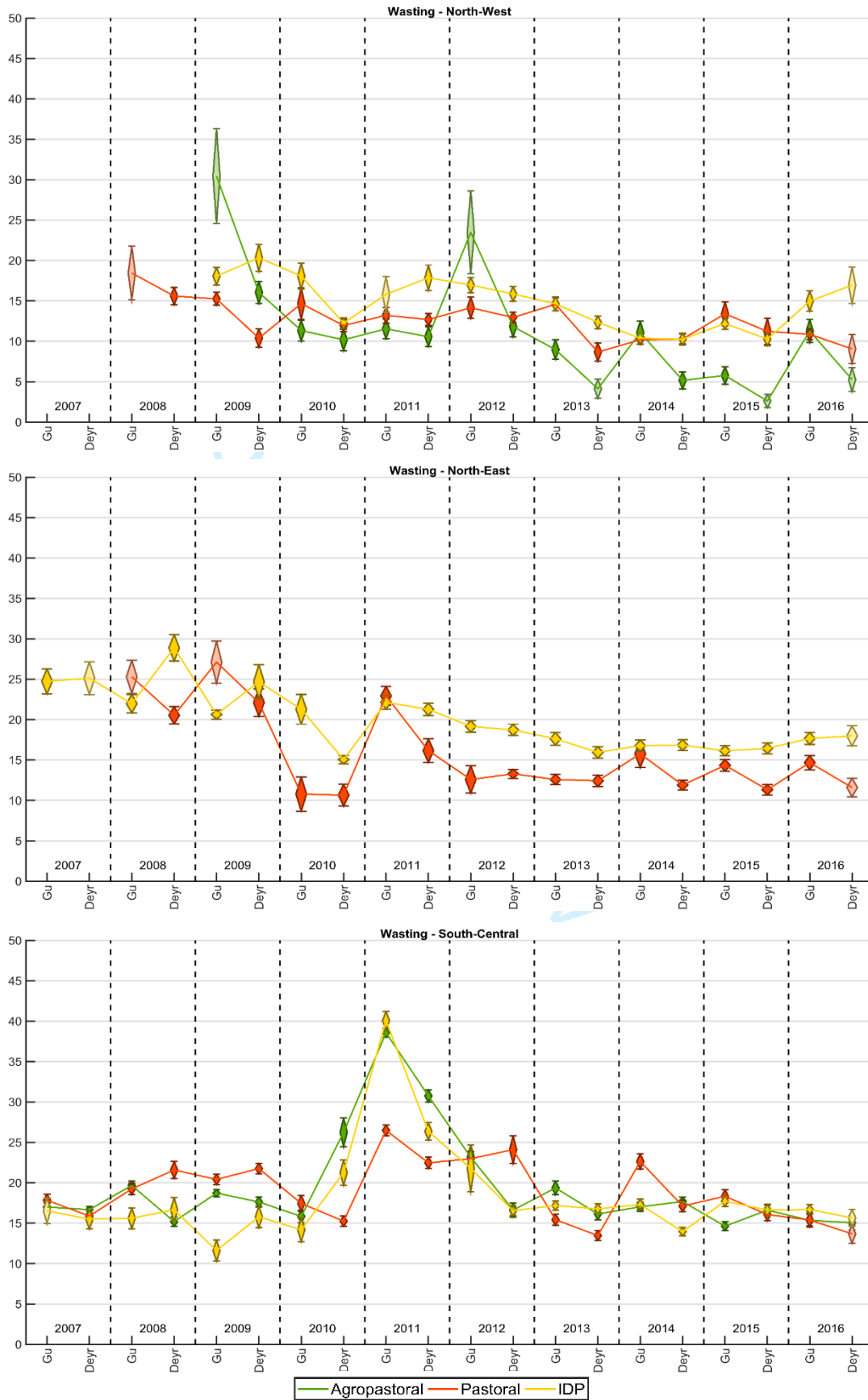
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21 696 **Figure 3.** Growth patterns cohorts of children 6-59 months in agro-pastoralists and
22 697 pastoralists populations in the South Central zone of Somalia
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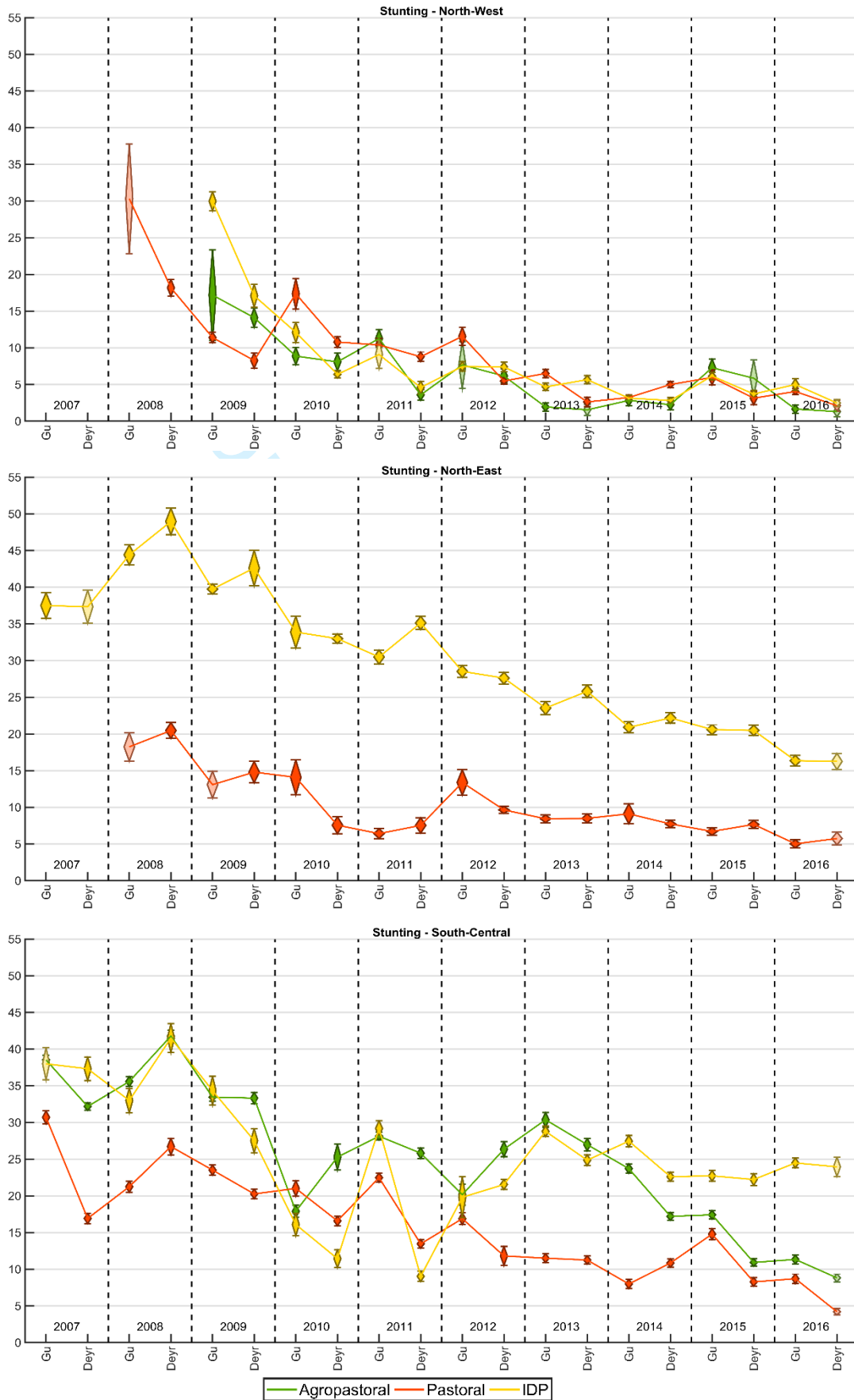
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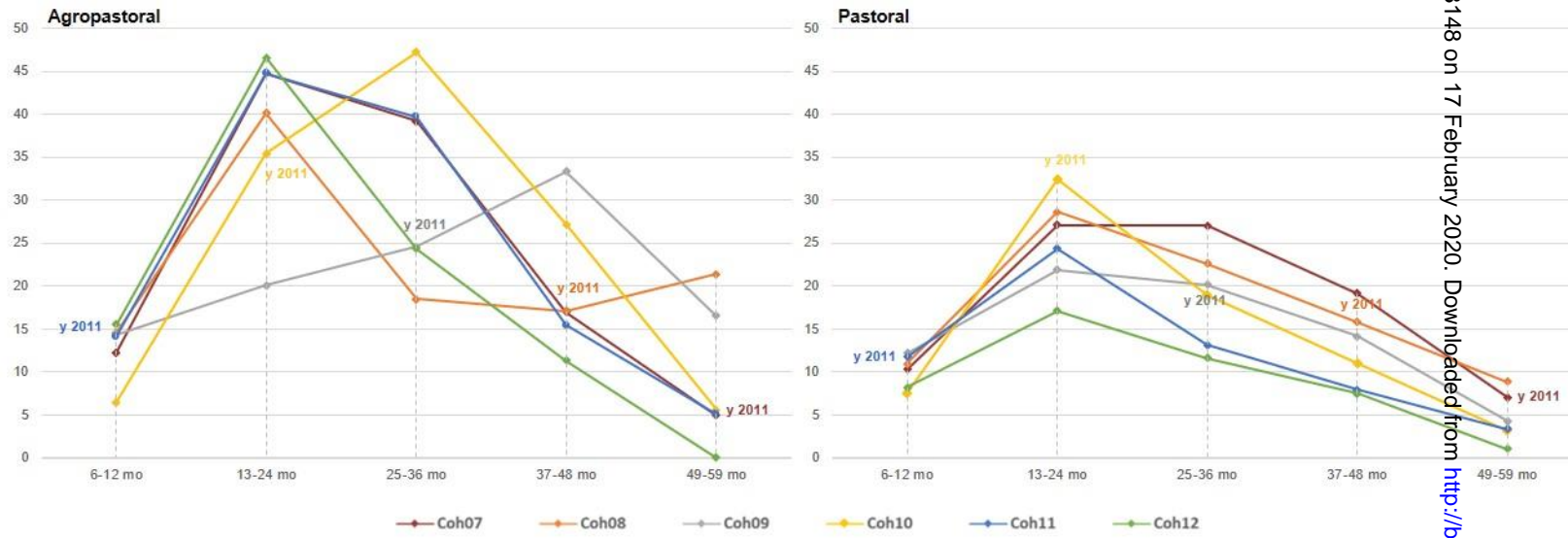
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28 700 **Figure 4:** Morbidity estimates and confidence intervals at 95% (diamond shapes) by year
29 701 and season of analysis for each livelihood and disaggregated in the three operational
30 702 zones (NWZ, NEZ and SCZ). Diamond shapes in lighter color depict estimations that were
31 703 imputed.
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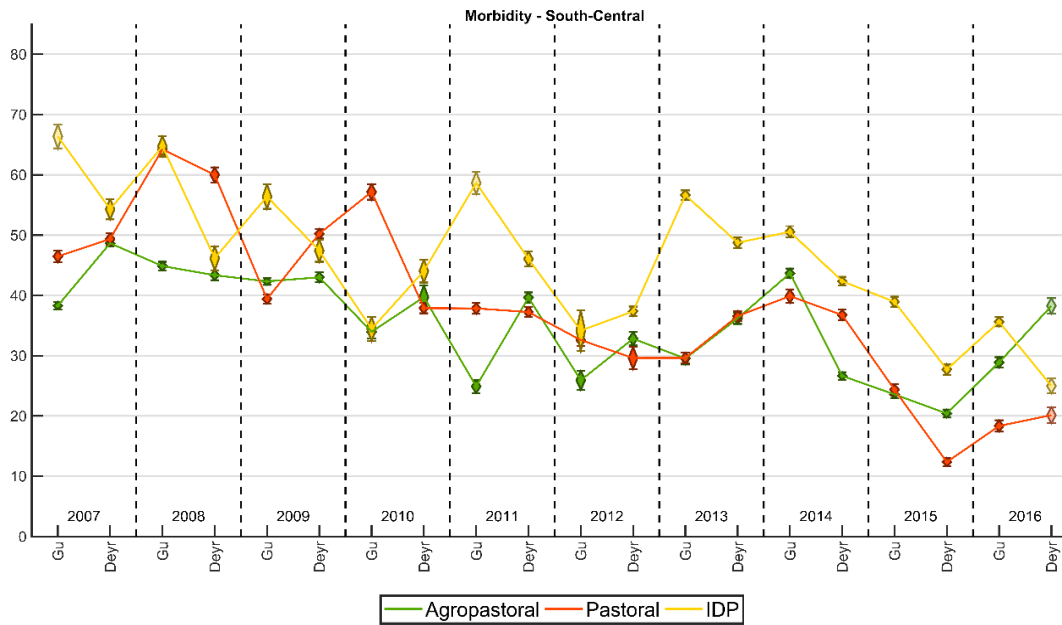
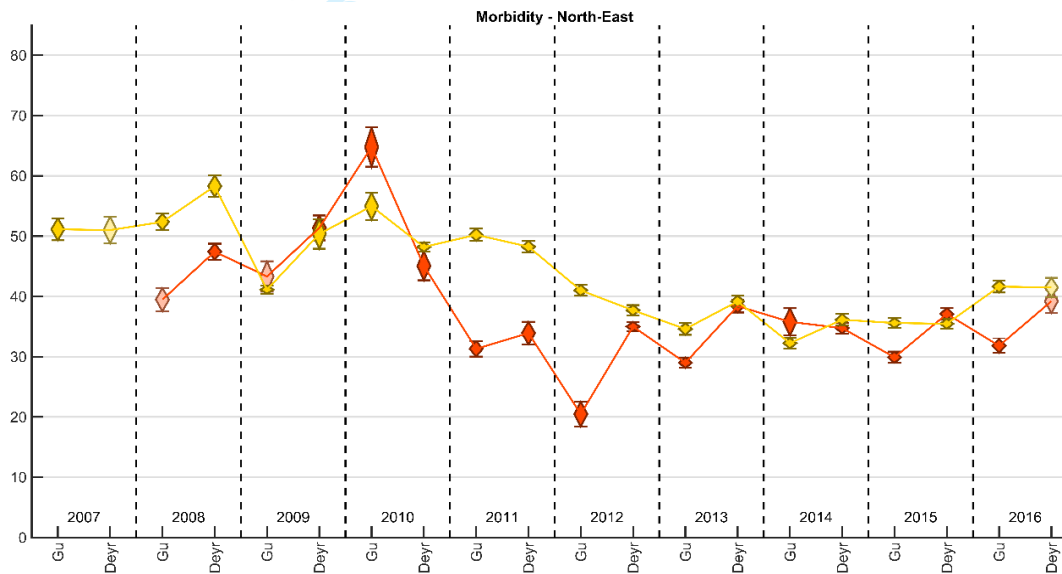
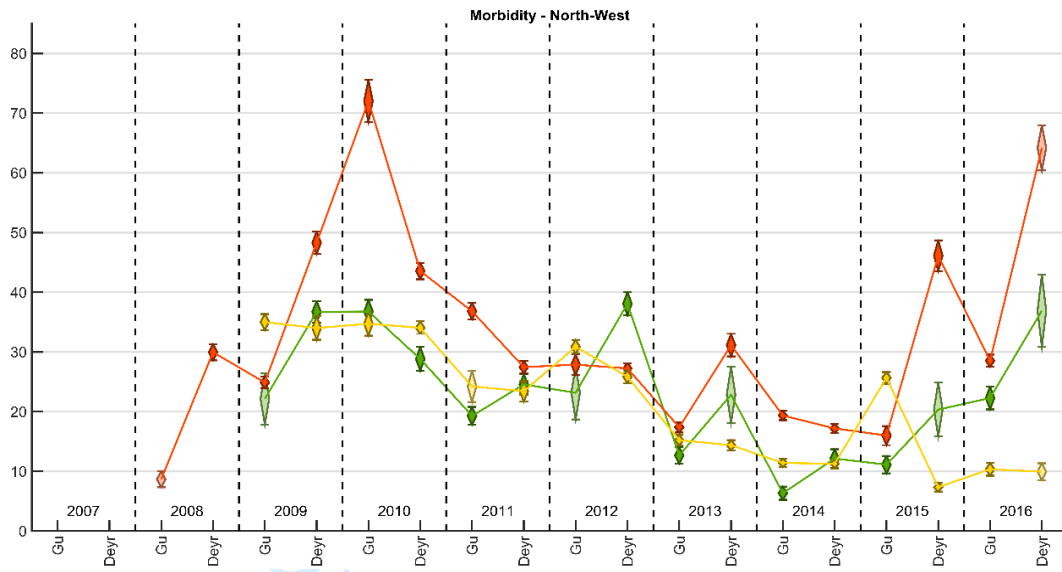
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Review only



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46**Annex 1.** Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr		
North West																				49585
Agropastoral					716	609	520	684	643		617	568			496	445	467		488	6253
Pastoral			1128	2045	702	334	1781	1203	1937	692	2594	1892	611		2639	2361	537	383	2253	23092
IDP					1251	585	570	2497		610	1597	1651	1713	1716	1975	1743	2179	1352	801	20240
North East																				69275
Pastoral				1407		588	213	516	1294	637	381	3701	2763	2083	450	2832	2383	2426	1614	23288
IDP	760		1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658	2913	3210	3393	3222	2574	45987
South Central																				163654
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,753	4,314	5,005	4,174	3,682	2,753	75,598
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,199	1,903	2,960	2,252	2,177	1,688	50,295
IDP		903	794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,411	3,183	4,648	3,309	2,646	4,141	37,761
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16433	17873	23204	18694	15888	16312	282514

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Annex 2

Supplementary Table 1: Sample size of the study by zone and livelihood system.

Zones	2007		2008		2009		2010		2011		2012		2013		2014		2015		2016	Total				
	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu	Deyr	Gu							
North West																				49585				
Agropastoral					716	609	520	684	643			617	568			496	445	467			488	6253		
Pastoral			1128	2045	702	334	1781	1203	1937	692	2594	1892	611			2639	2361	537	383			2253	23092	
IDP					1251	585	570	2497				610	1597	1651	1713	1716			1975	1743	2179	1352	801	20240
North East																				69275				
Pastoral					1407	588		213	516	1294	637	381	3701	2763	2083			450	2832	2383	2426	1614	23288	
IDP	760			1333	772	5165	413	484	5314	2365	2844	3015	3176	2376	2658			2913	3210	3393	3222	2574	45987	
South Central																				163654				
Agrop+Riverine	6,421	8,273	4,984	3,652	7,159	3,730	2241	617	7,416	3,726	764	1810	2127	2,755			4,314	5,005	4,174	3,682	2,753	75,598		
Pastoral	2,713	2,837	2,956	1,542	3,853	3,988	1,461	3,244	4,484	3,359	2,262	618	2,799	3,195			1,903	2,960	2,252	2,177	1,688	50,295		
IDP	903		794	624	594	734	578	682	1,874	1,684	202	3,703	4,043	3,411			3,183	4,648	3,309	2,646	4,141	37,761		
Total	9894	12013	10067	9125	20067	11456	6490	15171	19320	15440	8913	17870	18281	16436			17873	23204	18694	15888	16312	282514		

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60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-11
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9-11
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9-11
Bias	9	Describe any efforts to address potential sources of bias	3 & 10
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-11
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	10
		(b) Describe any methods used to examine subgroups and interactions	10
		(c) Explain how missing data were addressed	9
		(d) If applicable, describe analytical methods taking account of sampling strategy	8-9
		(e) Describe any sensitivity analyses	n.a.
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9-11
		(b) Give reasons for non-participation at each stage	n.a.
		(c) Consider use of a flow diagram	n.a.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	12-18
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	15-19 and 31

		(b) Report category boundaries when continuous variables were categorized	12-18
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n.a.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12-18
Discussion			
Key results	18	Summarise key results with reference to study objectives	19
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	3
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	19-23
Generalisability	21	Discuss the generalisability (external validity) of the study results	19-23
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	27

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.