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**Cohort Profile**



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# Cohort Profile: Basse Health and Demographic Surveillance System, the Gambia

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**Key Features**

- The Basse Health and Demographic Surveillance System (BHDSS) in rural Gambia was established to support population-based epidemiological research. Studies have used the Medical Research Council Unit, The Gambia (MRCG) Basse Field Station, to conduct large-scale, laboratory-linked disease surveillance, clinical trials, and intervention evaluations.
- The Basse Field Station was established in 1982. Research studies assisted in the establishment of the BHDSS. The first enumeration in 2007 estimated a population of 25 700 aged 0–4 years; 40 956 aged 5–14 years; and 75 238 aged ≥15 years.
- Data collected at the initial baseline, and subsequent household enumerations every 4 months, include relationships between household individuals, pregnancies and outcomes, births, deaths (causes determined by verbal autopsy), migrations, child vaccination, and geographic locations of households. The BHDSS has experienced <1% loss to follow-up and plans to continue household follow-up every 4 months.
- In December 2022, the estimated population was 31 110 aged 0–4 years; 63 706 aged 5–14 years; and 118 771 aged ≥15 years, with stable rates of fertility and falling rates of adult and child mortality.
- The BHDSS has hosted research on childhood diarrhea, pneumonia, invasive bacterial disease, and malaria. Data are available from the MRCG data management department (email: eezeani@mrc.gm, Head of HDSS).

## Why was the cohort set up?

The Medical Research Council Unit, The Gambia (MRCG) at the London School of Hygiene & Tropical Medicine (LSHTM) established the Basse Health and Demographic Surveillance System (BHDSS) in 2007. The system was set up to support two large, population-based surveillance studies, namely the Global Enteric Multicentre Study (GEMS) and the Pneumococcal Surveillance Project (PSP), both funded by Gates Foundation [1, 2]. Establishment of the BHDSS took advantage of an existing framework for the mapping and enumeration of villages and households in the area that was developed by two earlier clinical trials (funding—United States of America National Institutes of Health, Gates Foundation, and United Kingdom Medical Research Council) [3, 4]. Before this, MRCG had established a Field Station in 1982 in the town of Basse in Upper River Region (URR) (Fig. 1). This article begins by describing the early research in Basse and the establishment of the BHDSS. A description of the BHDSS follows. It concludes by describing the subsequent research hosted by the BHDSS. UKRI-MRC has funded the BHDSS and will continue funding as long as the MRCG Unit is in operation.

MRCG established the Basse Field Station to conduct research on schistosomiasis [5]. Studies of child mortality, malaria, pneumonia, and invasive bacterial disease soon followed [6–8]. Subsequent studies added the structures required for demographic surveillance.

A phase III trial to evaluate the efficacy of a 9-valent pneumococcal conjugate vaccine (PCV9) in infants was conducted from 2000 to 2005 [3]. This trial mapped all the settlements in URR assigning codes to each village and residential compound. PCV9 proved highly effective, leading to a World Health Organization (WHO) recommendation for global use.

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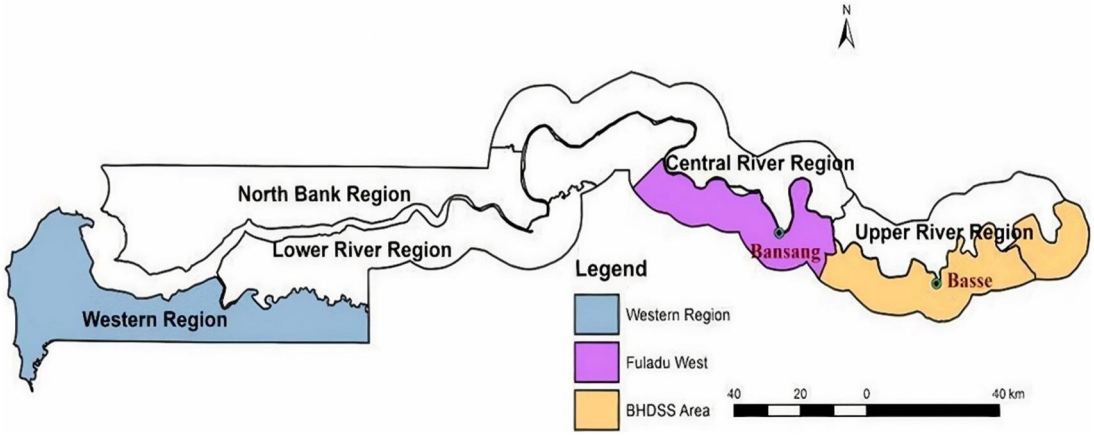



**Figure 1.** Map of the Gambia with the location of the Basse Health and Demographic Surveillance System in Upper River Region in eastern Gambia.

In 2006, children <5 years of age living in URR on the south bank of the Gambia River (Fig. 1) were enumerated to support a trial evaluating strategies for intermittent preventive treatment of childhood malaria [4]. These two studies provided mapping and a structure for identification of households and individuals which facilitated the later implementation of the BHDSS.

All procedures and structures for the BHDSS were set up in early 2007, and the first census was completed in October 2007. The BHDSS was established to provide population-based estimates of the incidence of childhood diarrhea in GEMS [1] and pneumonia and invasive pneumococcal disease in PSP [2]. Both GEMS and PSP combined population-based surveillance for clinical episodes in all health facilities in the BHDSS with standardized investigation and analysis in the Basse Field Station laboratory. GEMS used BHDSS population denominators to calculate the incidence of moderate-severe diarrhea in young children and found that Rotavirus, *Shigella*, *Cryptosporidium*, and Norovirus were the primary etiological pathogens. PSP calculated the incidence of radiological pneumonia and invasive pneumococcal disease in children and adults, before and after the national introduction of PCV in 2009. After 5 years, the incidence of vaccine-type invasive pneumococcal disease in the 2–23 month age group had declined by 82% [9] and radiological pneumonia by 24% [10]. After 8 years, the incidence of vaccine-type invasive pneumococcal disease in the 2–59 month age group had declined by 92% and radiological pneumonia by 33% [10].

The main aims of the BHDSS are to:

1) Generate longitudinal demographic information in a large, geographically defined population in rural Gambia.
2) Provide a high-quality demographic platform for large epidemiological studies, both observational and interventional.
3) Measure the impact of population-level interventions aimed at improving the health of the local population.

## Who is in the cohort?

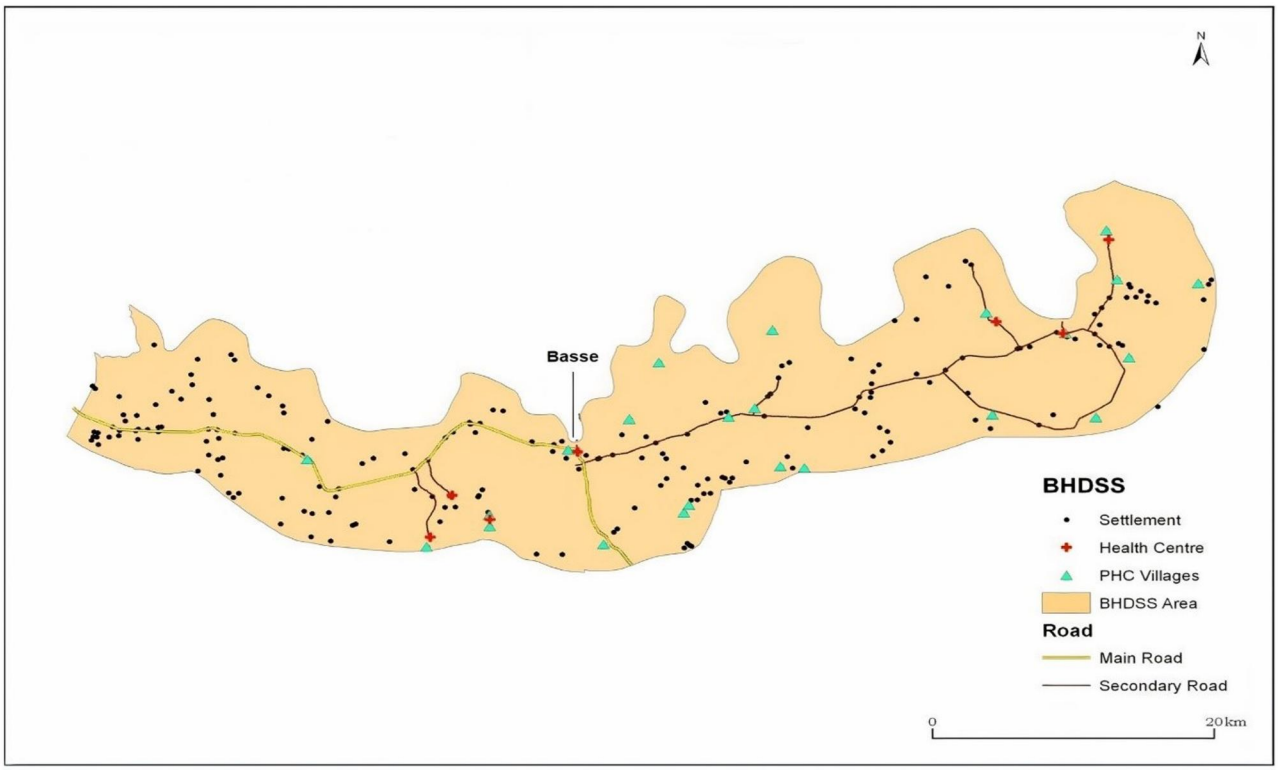
The BHDSS is situated on the south bank of URR, the most easterly region of The Gambia (Fig. 1). Three main ethnic groups live in the area, Serahule, Fula, and Mandinka. Families are commonly headed by one individual with wives and children, often in polygamous marriages. Extended families frequently reside together. Residents live in fenced compounds, which may include multiple households. A household consists of individuals sharing the same living space and cooking arrangements [11]. The population of the BHDSS in 2020 was 201 866, living in 224 villages (Fig. 2) with 19 644 households distributed in 9668 compounds. The area is predominantly rural with 60% of the population residing in small villages. Thirty-seven percent of the Gambian population resides in rural areas [12].

The BHDSS covers all residents in the geographical area. A resident is defined as any person residing in the area at two consecutive household visits, scheduled every 4 months. Residents are "present" or "absent," depending on whether he/she has spent the night preceding the enumeration visits; those absent at two consecutive visits are considered emigrants. Initial recruitment of individuals and households occurred during the first full enumeration in October 2007. Existing identification numbers for 219 villages (five digits), 6275 compounds (four digits), and 9299 households (two digits) were used while adding a sequential individual identification number (three digits) for all individuals in one household. Thus, all residents have a unique 14-digit identification. Sequential individual identification numbers in a household begin with the head of household designated 001. The population in October 2007 was 136 387. Individuals were then added to the BHDSS by birth or in-migration. Five new villages have emerged and been added. Households have been added when new dwellings are constructed and occupied. The BHDSS is linked to the local health system using the 14-digit identification numbers of patients presenting to health facilities [13].

Ethics approval for projects and the BHDSS have been granted by the Gambia Government/MRC Joint Ethics Committee. Verbal consent is obtained from the household head or respondent at each household visit.

## How often have they been followed up?

Since 2008, field assistants have visited all BHDSS households every 4 months to record births, deaths, pregnancies, migrations, ethnicity, and educational levels of individuals. During each visit, staff enquire whether new demographic events have occurred in the household since the previous visit. If individuals are absent or unavailable an alternative




Note: PHC primary health care village.

**Figure 2.** Map of the Basse Health and Demographic Surveillance System.

**Table 1.** Measurements made at baseline or made once for an individual

| Phase | Measurements | Type of questionnaire |
|---|---|---|
| Baseline 2007 | Village number, compound number, household number, and individual demographics of all residents. | Structured interviews with a household listing questionnaire |
| Indicators are recorded once for an individual | Compound geographical position coordinates of existing and new compounds, individual identity number (14-digits combining a 5-digit village number, 4-digit compound number, 2-digit household number, and 3-digit individual number), individuals' name, place of birth and date of birth, birthweight (when available), name of newborn, sex, ethnicity, mother's and father's names and individual identity numbers, place of death and date of death, verbal autopsy, highest educational level. | Household listing questionnaire |

respondent for the household reports on the residency status of individuals listed in the household. If there is no respondent available for a household the visit is rescheduled for later in the 4-month period. Only nine of 19 350 households have consistently declined enumeration, primarily due to negative perceptions of MRCG. In the event of individuals changing houses, the event is captured as a compound location change. Each individual has an 11-digit current location identification based on the village, compound, and household in which they currently reside. There has been little or no drop-out of households.

## What has been measured?

The BHDSS conducted an initial census enumerating individuals of all ages with individual identifications (Table 1). Regular 4-monthly enumerations began in January 2008 with follow-up of all individuals in all but nine of 19 350 households. The population has grown to 213 587 in December 2022. The BHDSS collects demographic data on individuals (first name, surname, date of birth, sex, and relationship to the household head), pregnancies and pregnancy outcomes, births and the dates, deaths and the dates, verbal autopsies, migrations and the dates, and dates of child vaccination (Tables 1 and 2). We have used these data to measure rates of fertility, birth, death, mortality in adults and children aged <5 years, in-migration, and out-migration (Table 3). Vaccination data are used to calculate vaccine coverage. We have used geographical position data to map public health service areas (Supplementary Fig. S1) and the locations of disease cases, for example, diarrhea (Supplementary Fig. S2).

### Cause of death

About 40 days after the event, a relative of the deceased who was present at the time of death is approached for the conduct of WHO 2016 Verbal Autopsy questionnaires. Probable

**Table 2.** Measurements made every 4 months for each household

| Data point | Information collected/individual characteristics | Type of questionnaire |
|---|---|---|
| Household, compound, and village | Village number, compound number, household number, compound head name, and individual identity number. | Household questionnaire |
| Individuals | Names and individual identity numbers, current residential status, current residential compound, relationship to head of household, occupation. | Structured interviews with household questionnaire |
| Births | Data indicated in Table 1. | DHS questionnaire |
| Pregnancies | Woman's name and individual identity number, date of last menstrual period, pregnancy outcome (live birth, stillbirth, miscarriage), delivery date, and newborn birth details are in Table 1. | DHS questionnaire |
| Deaths and VA | Name and individual identity number of deceased, death details in Table 1, females 12–55 years old: pregnancy or delivery-related death. VA for adults, children, and neonates. | DHS questionnaire. WHO 2016 VA questionnaire |
| Migrations | Migrant's name and individual identity number, date of in-migration, type of in-migration (internal/external), place of previous and new village and compound, individual information in Table 1, date of out-migration, type of out-migration (internal/external), place of previous and new village and compound, i.e. destination if known, individual information in Table 1. | DHS questionnaire |
| Vaccinations | Type and date received for all nationally recommended vaccines. | Vaccination questionnaire |

DHS, Demographic Health Survey; VA, verbal autopsy; WHO, World Health Organization.

**Table 3.** Demographic characteristics of the Basse Health and Demographic Surveillance System, in the decade 2011–20

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016[a] | 2017 | 2018 | 2019 | 2020 |
| Total births | 6936 | 7666 | 7436 | 7546 | 6663 | 5771 | 6075 | 6524 | 6913 | 6580 |
| Total deaths | 1384 | 1379 | 1279 | 1202 | 1422 | 1014 | 1128 | 1175 | 1087 | 1187 |
| Total pregnancies | 6942 | 7764 | 6998 | 7521 | 6420 | 5348 | 6001 | 6783 | 8126 | 7221 |
| Live birth pregnancies | 6593 | 7414 | 6645 | 7143 | 5970 | 5154 | 5670 | 6445 | 7563 | 6525 |
| Infant deaths | 179 | 175 | 177 | 170 | 148 | 71 | 122 | 112 | 112 | 145 |
| Adult deaths (≥18 years) | 754 | 790 | 713 | 738 | 928 | 702 | 809 | 869 | 780 | 829 |
| Verbal autopsies | 1370 | 1347 | 846 | 478 | 369 | 884 | 851 | 1096 | 814 | 523 |
| Rates | | | | | | | | | | |
| Crude birth[b] | 41.4 | 44.4 | 42.2 | 42.1 | 37.0 | 31.7 | 32.7 | 34.3 | 35.2 | 32.6 |
| Crude death[b] | 8.3 | 8.0 | 7.3 | 6.7 | 7.9 | 5.6 | 6.1 | 6.2 | 5.5 | 5.9 |
| General fertility rate[c] | 155 | 169 | 147 | 154 | 126 | 109 | 116 | 128 | 144 | 121 |
| Under five mortality[d] | 70.8 | 59.3 | 68.3 | 51.8 | 58.6 | 43.1 | 40.0 | 33.0 | 29.5 | 40.5 |
| Infant mortality[d] | 27.2 | 23.6 | 26.6 | 23.8 | 24.8 | 13.8 | 21.5 | 17.4 | 14.8 | 22.2 |
| Adult mortality[b] | 4.5 | 4.6 | 4.0 | 4.1 | 5.1 | 3.9 | 4.4 | 4.6 | 4.0 | 4.1 |
| In-migration[b] | 101 | 103 | 74.1 | 60.3 | 51.1 | 41.5 | 37.7 | 46.7 | 40.7 | 39.0 |
| Out-migration[b] | 69.7 | 65.4 | 43.2 | 28.2 | 26.0 | 35.4 | 21.4 | 19.8 | 14.2 | 12.5 |
| Rate of natural increase[e] | 33.1 | 36.4 | 34.9 | 35.4 | 29.1 | 26.1 | 26.6 | 28.1 | 29.7 | 26.7 |
| Female pop. (15–49 years) | 42 653 | 43 784 | 45 235 | 46 351 | 47 378 | 47 497 | 48 809 | 50 388 | 52 353 | 53 886 |
| Total population | 167 672 | 172 778 | 176 387 | 179 200 | 180 230 | 181 968 | 185 657 | 190 365 | 196 117 | 201 866 |

[a] Data as of 11 March 2022. In 2016/17, the number of births and infant deaths was substantially lower than expected because of technical problems with the implementation of the electronic data capture system and incomplete household enumeration.
[b] Per 1000 population.
[c] Per 1000 women of reproductive age.
[d] Per 1000 live births.
[e] Difference (±) between the crude birth rate and the crude death rate (see Supplementary Table S1).

causes of death are determined by research clinicians using International Classification of Diseases-10 coding as well as by the InterVA algorithm [14].

## Data collection and management

The surveillance area is divided into zones (Supplementary Fig. S1). The sequence of household visits within each zone is maintained in each enumeration round. Initially, BHDSS data were recorded on paper using standardized report forms with data then entered into a database. In 2016, data collection transitioned to electronic capture, with an offline Android application on tablet devices that are periodically synchronized to a central database. Demographic detail forms are downloaded to the tablet for field data collection using a REDCap (version 8.9.2, Vanderbilt University) Demographic Surveillance Application (DSA). If household

enumeration visits detect new demographic events since the previous visit, the relevant DSA form is completed. Implementation of the DSA in 2016 experienced technical difficulties that led to interruption of enumeration rounds and incomplete detection of demographic events.

## What has it found?

The population of the BHDSS is young, with about two-thirds (68%) aged <25 years, and only 4% of the population aged >60 years (Fig. 3). There are more females (54%) than males, probably due to the substantial migration of young men to the coast or abroad. While the BHDSS collected regular demographic and household enumeration data from 2008, we report here on the period 2011 to 2020, which incorporates demographic trends over one decade. Annual population estimates and annual event rates were generated for each year using the available data. While some events were missed in 2016, the analysis over a decade, allows appreciation of the long-term demographic trends in the population. The demographic trends in this decade show a rapidly growing population with decreasing mortality in both adults and young children (Table 3). The BHDSS annual population growth rate was estimated at 2.0%, with the total population increasing from 167 672 to 201 866. This is a result of a relatively stable crude birth rate (37.4/1000), and a decreasing crude death rate, from 8.3/1000 in 2011 to 5.9/1000 in 2020. Indeed, under-5 mortality fell on average by 5% per year, from 70.8 to 40.5 per 1000 live births, and adult mortality by 0.4% per year, from 4.5 to 4.1 per 1000. The general fertility rate in 2011 was 155 births per 1000 women of reproductive age and 121 per 1000 in 2020 (Table 3). The apparent drop in numbers of births and infant deaths in 2016 is probably due to incomplete detection. In April 2020, data collection was suspended for 4 months at the beginning of the COVID-19 pandemic and restarted in September 2020 without further interruption. Despite these interruptions, the system can record any reported demographic events in a household that have not been previously recorded.

### What research has been conducted?

Initial studies in Basse from 1989 to 1992 focused on pneumonia and malaria, highlighting significant clinical similarities between pneumonia and malaria and a need to consider both conditions in diagnosing febrile illnesses, especially where pneumonia and malaria are common [8]. The Basse Field Station was a site in the evaluation of The Gambia's National Insecticide Impregnated Bednet Program from 1991 to 1992, which reported a 25% reduction in all-cause mortality among 1–9-year-olds in intervention villages [15].

A pivotal trial evaluated the efficacy of PCV9, demonstrating 37% efficacy against radiological pneumonia and 77% efficacy against vaccine-serotype invasive pneumococcal disease [3]. PSP subsequently confirmed the real-world effectiveness of PCV when implemented in the routine national immunization schedule [2, 9, 10, 13].

Over its 10 years duration, PSP provided the opportunity for several ancillary studies. In 2012, the project enabled early detection and control of an epidemic of meningococcal meningitis [16], PSP also documented parallel 70% declines in invasive Salmonella disease and malaria with no observed reduction in invasive pneumococcal disease [17]. The incidence of invasive disease due to *Haemophilus influenza* type b (Hib) and the impact of Hib vaccination were also

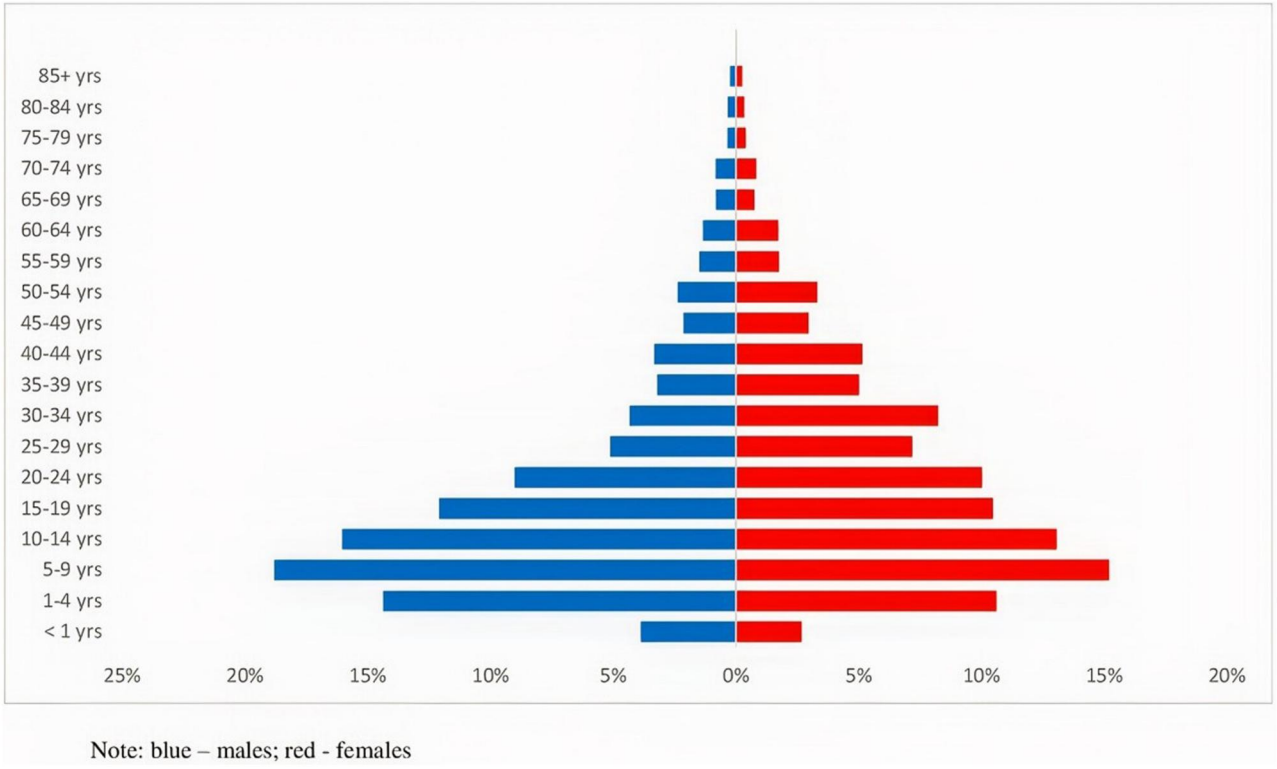



**Figure 3.** Static population pyramid of the Basse Health and Demographic Surveillance System, December 2020.

estimated [18]. Data from both PSP and the BHDSS were used to estimate the mortality rate of children in the 6 months following their discharge from Basse Hospital, highlighting the respective 7- and 24-times increased risk of post-discharge mortality in moderately and severely malnourished children [19]. In addition, the BHDSS supported two studies on the etiology of pneumonia, highlighting the primary role of pneumococcus and Respiratory Syncytial Virus [20, 21]. A randomized trial found no benefit of adjunctive zinc therapy for pneumonia [22]. A multicenter phase III trial in Basse led to the national and international introduction of group A conjugate meningococcal vaccine [23]. As previously mentioned, GEMS highlighted the dominant role of Rotavirus in the etiology of childhood diarrhea. Following GEMS, the BHDSS provided the platform for further surveillance of childhood diarrhea, investigating its causes and the impact of the national introduction of Rotavirus vaccine on the incidence of diarrhea [24]. Diarrhea surveillance is currently ongoing, with a focus on Enterotoxigenic *Escherichia coli* [24].

Over the recent decades, malaria transmission has decreased substantially in The Gambia, including URR [25]. Studies of malaria transmission over time and the effect of several new control strategies have been implemented. Cross-sectional surveys of malaria infection were implemented both in the dry and rainy seasons in 2008, 2009 [26], 2013 [27], and 2014, with prevalence consistently <10%. There have been studies on malaria in pregnancy, including one on systematic screening between antenatal visits, which was not associated with clear benefits [28]. Malaria research is now focused on understanding residual malaria transmission, and interventions to further decrease transmission toward elimination, such as combining indoor residual spraying of dichlorodiphenyltrichloroethane with insecticide-treated nets, or modified house structure to reduce vector entry and exposure, neither of which was associated with reductions in malaria. A cluster-randomized trial of mass administration of ivermectin and dihydroartemisin-piperaquine reported a 70% reduction in malaria prevalence in intervention villages [29].

The BHDSS is currently supporting a large cluster-randomized trial comparing the standard PCV schedule of three doses with a two-dose schedule [30] by confirming participants' residential village, migrations, deaths, and individual-level person-time for incidence analysis. More than 20 studies have been conducted from the Basse HDSS cohort.

## What are the main strengths and weaknesses?

The BHDSS now provides continuously updated demographic information for more than 210 000 inhabitants in rural Gambia. Participation in the routine demographic surveillance is high.

The primary strength of the BHDSS is its ability to support large-scale population-based, laboratory-linked, epidemiological, and disease surveillance studies. The platform can host a range of scientific investigations requiring prospective follow-up of participants. Studies requiring the recruitment of contacts for index cases can also be accommodated. The system continues to receive the support of regional, district, and village authorities, as well as the cooperation of residents.

However, there are important limitations. Despite the potential for demographic events that occur during a period when household enumeration visits are omitted, to be reported at the next visit, it appears that in 2016 there was incomplete detection of events, particularly pregnancies, births, and infant deaths (Table 3). The Corona virus (COVID-19) pandemic caused one round of enumeration in 2020 to be missed. When household visits resumed in September 2020, after a 4-month interruption, we were particular that staff enquire about events that occurred throughout the whole of 2020. It is difficult to determine if demographic events that occurred during these interruptions were not reported but events could have been reported at the next household visit.

## Can I get hold of the data? Where can I find out more?

Information about the BHDSS can be found at (https://www.mrc.gm) or by contacting Dr E Ezeani, eezeani@mrc.gm. Data-sharing is guided by an MRCG Unit policy.

## Ethics approval

The BHDSS was approved by the Gambia Government/MRCG Joint Ethics Committee (numbers 1247 and 28301). The BHDSS adheres to the Declaration of Helsinki by ensuring the confidentiality of personal data. The BHDSS involves household-level consent, with the household head giving verbal consent at each visit with permission for data collection documented at each visit.

## Acknowledgements

We thank all current and former residents of the BHDSS for their participation. We acknowledge the contributions of members of the Unit, including the Unit Demographer, in the initial establishment of the system, especially our software developers and the data management and archives team, in the enhancement of the database management system. We sincerely thank our HDSS users and the senior management of the MRCG at LSHTM. We are also grateful to all district authorities, village leaders, and former heads of the MRC Basse Field Station for their significant contributions toward the maintenance of the BHDSS. We also acknowledge the assistance over the years of the HDSS data and field staff.

## Author contributions

E.S.E.: coordinated BHDSS activity, analyzed and interpreted data, drafted the manuscript; G.S.: coordinated BHDSS activity, designed the data collection system, analyzed and interpreted data; A.R.: interpreted data; J.M.H. and M.I.H.: coordinated BHDSS activity, interpreted data; F.S.A.: designed the data collection system, coordinated BHDSS data management activity, interpreted data; U.D.: interpreted data; G.M.: coordinated BHDSS activity, coordinated surveillance for meningitis, sepsis, and pneumonia from 2008 and ongoing, interpreted data, revised the manuscript. All authors read, critically revised the manuscript for intellectual content and approved the final manuscript. E.S.E. and G.M. are guarantors of the paper.

## Supplementary data

Supplementary data are available at *IJE* online.

## Use of artificial intelligence (AI) tools

No AI tool was used to collect or analyze data but picture picture-enhancing resolution tool (PhotoDiva) was used.

Conflict of interest: None declared.

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## Data availability

See 'can I get hold of the data?' above.

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Cohort Profile