

## HEALTH AND DEMOGRAPHIC SURVEILLANCE IN RURAL WESTERN KENYA: A PLATFORM FOR EVALUATING INTERVENTIONS TO REDUCE MORBIDITY AND MORTALITY FROM INFECTIOUS DISEASES

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**Abstract.** We established a health and demographic surveillance system in a rural area of western Kenya to measure the burden of infectious diseases and evaluate public health interventions. After a baseline census, all 33,990 households were visited every four months. We collected data on educational attainment, socioeconomic status, pediatric outpatient visits, causes of death in children, and malaria transmission. The life expectancy at birth was 38 years, the infant mortality rate was 125 per 1000 live births, and the under-five mortality rate was 227 per 1,000 live births. The increased mortality rate in younger men and women suggests high human immunodeficiency virus/acquired immunodeficiency syndrome-related mortality in the population. Of 5,879 sick child visits, the most frequent diagnosis was malaria (71.5%). Verbal autopsy results for 661 child deaths (1 month to <12 years) implicated malaria (28.9%) and anemia (19.8%) as the most common causes of death in children. These data will provide a basis for generating further research questions, developing targeted interventions, and evaluating their impact.

### INTRODUCTION

Incomplete or nonexistent vital event and health registration systems in most developing countries pose a particular challenge to the development of effective health policies and programs. Data for evaluating program effectiveness, measuring the efficacy of interventions or setting priorities for resource allocation are frequently obtained using health facility data or cross-sectional surveys: the former may be biased through differential attendance and the latter may lack an adequate population sampling frame. Neither health facility nor cross-sectional data permit evaluation of longitudinal trends in morbidity or mortality related to sex, age, geographic distribution or socioeconomic status.

A Health and Demographic Surveillance System (HDSS) is a longitudinal, population-based health and vital event registration system that monitors demographic (e.g., births, deaths, pregnancies, and migrations) and health (e.g., clinic attendance and hospital admission) events in a geographically defined population with timely production of data.<sup>1</sup> This continuous surveillance makes it possible to easily and clearly define risks of demographic and health events for individuals over time. The HDSS can provide a cause-specific mortality and morbidity profile that is demographically or geographically stratified, permitting rational resource allocation to priority diseases in defined target groups. Accurate sampling frames can be generated from HDSS data at multiple levels (individual, house, village) and by several strata (age, sex, geographic location) to permit unbiased, population-based sampling. The longitudinal morbidity, mortality, and fertility data generated from the HDSS can help generate hypotheses on the causes of disease and death in the population and evaluate the impact of public health interventions. Finally, significant efficiencies may be achieved when multiple re-

search or program evaluation activities operate from the same infrastructure and population base.

In September 2001, the U.S. Centers for Disease Control and Prevention (CDC) in collaboration with the Kenya Medical Research Institute (KEMRI) launched an HDSS in Siaya and Bondo Districts in western Kenya modeled after systems developed in Ghana and Tanzania.<sup>2,3</sup> This HDSS measures morbidity, mortality (all-cause and cause-specific), fertility, migration, use of health facilities, and malaria transmission parameters. The main objective of the CDC/KEMRI HDSS is to provide an infrastructure for future evaluation of population-based public health interventions, including intermittent preventive therapy for malaria in infants and prevention, counseling, testing, and treatment for human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). Additionally, data generated by the HDSS stratified by age, sex, socioeconomic status, educational level, and geographic location can be used to generate hypotheses and address the causes of morbidity and mortality in subgroups of the population. We present the methods of our data collection procedures, selected results, and operational challenges encountered during the first year of study.

### MATERIALS AND METHODS

**Study area.** The demographic surveillance area (DSA) is located in a rural part of Nyanza Province in western Kenya in Asembo (Rarieda Division, Bondo District) and Gem (Yala and Wagai Divisions, Siaya District (Figure 1)). The DSA covers 217 villages (75 in Asembo and 142 in Gem) spread over a land area of approximately 500 km<sup>2</sup> along the shores of Lake Victoria. Before launching the HDSS, the DSA was the site of a randomized controlled trial of insecticide-treated bed nets (ITNs) from 1997 to 2002.<sup>4,5</sup>

As part of the ITN trial, a baseline census of the DSA population was conducted in 1996, followed by biannual updates to provide demographic information for the evaluation of ITNs.<sup>6</sup> Although all villages in the DSA have been under

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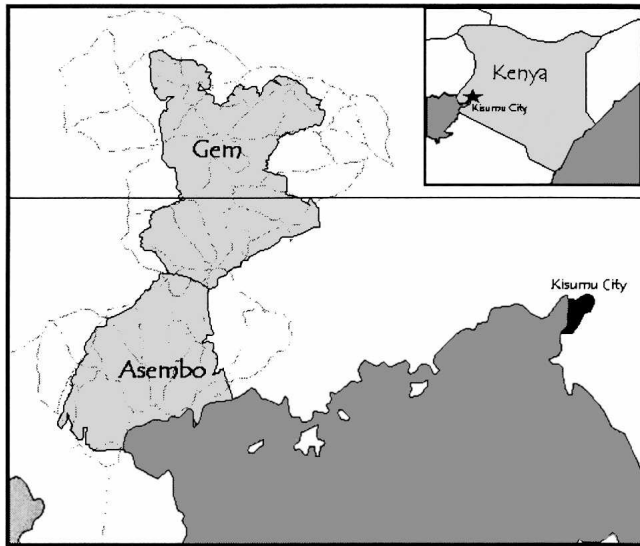


FIGURE 1. Location of the demographic surveillance areas in western Kenya.

demographic surveillance since 1997, this report includes only data from 2002.

**Study population.** The DSA population is culturally homogeneous (more than 95% are of the Luo ethnic group) and lives in dispersed settlements. Marriage is exogamous and patrilocal; polygyny is practiced. Houses are made of mud, cement, or brick with roofs of iron sheets or thatch. They are predominantly clustered into compounds comprised of houses for the male head of household, his wives, and unmarried sons. Compounds are dispersed and lie adjacent to the households' agricultural fields. Subsistence farming is the mainstay of the local economy. Rainfall is seasonal with the heaviest (long) rains usually occurring from March through May and short rains falling between September and November. Local crops include maize, sorghum, cassava, and millet. Because employment opportunities are limited, many young adults temporarily migrate to the urban areas to seek employment.

Malaria transmission is intense and perennial in lowland areas around Lake Victoria. However, the ITN trial conducted from 1996 to 2002 reduced malaria transmission in the DSA by 90%.<sup>7</sup> Continued provision of free ITNs and insecticide has maintained transmission at that level.<sup>5</sup> Despite the significantly reduced malaria transmission intensity, malaria infection is still common. In June–July 2003, a cross-sectional survey in Gem found that 60% percent of children less than five years of age and 36% percent of pregnant women were infected with malaria (van Eijk A and others, unpublished data). Other common pediatric infectious diseases in the DSA include upper respiratory tract infections, pneumonia, and diarrhea.<sup>8</sup>

HIV/AIDS is a serious health problem in western Kenya. In a cross-sectional survey conducted in the DSA in 2003–2004, the age-adjusted HIV prevalence rates in men and women 13–34 years of age were 11% and 21%, respectively with significantly higher rates in certain age and sex groups (Amornkul P and others, unpublished data). The rate of tuberculosis case notification in Nyanza Province was the highest of all the provinces in Kenya.<sup>9</sup>

**Core demographic surveillance.** A baseline census of the population of the DSA was conducted from September through December 2001 in Asembo and from May through August 2002 in Gem. Although the earlier ITN trial had included demographic surveillance, the data structure was not compatible with the relational database system adopted for the HDSS. A new baseline survey was conducted rather than attempting to convert the previous dataset into the new format.

All houses were mapped using a differential global positioning system as part of the ITN trial,<sup>10</sup> and maps were updated at least annually to take account of new construction. A unique location code was painted on each house consisting of codes identifying the village, compound, and house. At the baseline survey and upon birth or in-migration, all residents were given a unique, permanent identification number composed of this location code plus a three-digit individual number.

Household surveillance was conducted through house-to-house interviews by trained staff on a rolling basis through three rounds in each calendar year (January through April, May through August, and September through December). During the household interviews, all pregnancies, births, deaths, and migrations that occurred since the previous visit were recorded in a hand-held register and on scannable data forms created using Cardiff Teleforms (Cardiff Software Inc., Vista, CA). New household occupants identified on the day of the staff visit were asked for the date of their arrival in the compound; individuals who had not yet been resident for four calendar months were provisionally recorded on the back of the household register form for follow-up at the next visit. After four calendar months of residence, persons were registered as new in-migrants and given permanent identification numbers. Previously registered residents who were reported as no longer residing in the house on the day of the visit were provisionally recorded as being out of the area, but were not considered to have out-migrated until they had been away for four consecutive calendar months. Trans-migrations within the DSA were subject to the same rules of residence. In- and out-migrations within the DSA were reconciled by dedicated staff to conserve permanent identification numbers.

**Socioeconomic and education status.** During one round each calendar year, socioeconomic surveys were conducted on all households. Information collected included material used for house construction, occupations of the household head and spouse, household's primary source of drinking water, methods of water treatment, use of cooking fuel, and ownership of items such as livestock, radios, bicycles, and televisions. During a different round, current educational status and level of literacy in English and Kiswahili, a common language in Kenya, were updated for all individuals. Socioeconomic status and education data were collected to be used as covariates in analyses of causes of morbidity and mortality.

**Health facility surveillance.** To monitor changes in causes of morbidity in children, and in particular the proportion of visits due to malaria and anemia, outpatient health facility surveillance for pediatric (<10 years old) visits for Asembo began in 1997 and for Gem in mid-2002.<sup>8</sup> Although Kenya adapted the Integrated Management of Childhood Illness (IMCI) algorithm in March 2000, by 2002 no health care workers in Asembo or Gem had yet received training. Caregivers of all children attending any of 14 outpatient facilities

in Asembo and Gem for either sick or immunization visits were interviewed by trained study staff reviewing the child's health and treatment history over the past two weeks. After being examined by the clinic's nurse or clinical officer, symptoms noted and diagnoses made by the health practitioner and all prescriptions or drugs provided were recorded by study staff. Although health care workers had not been trained in IMCI, we adapted the IMCI algorithm to retroactively classify children in broad diagnostic categories. Study staff attempted to find both the child and the mother's permanent identification numbers in line lists of registration logs and enter them on the clinic visit form to link clinical and demographic data.

**Verbal autopsies.** We modified a standardized verbal autopsy questionnaire developed for use by HDSS sites around the world to accommodate the western Kenya situation ([http://www.indepth-network.org/core\\_documents/indepthtools.htm](http://www.indepth-network.org/core_documents/indepthtools.htm)). The questionnaire requested information on the child's terminal illness from a caregiver and included a brief section on health care sought during this illness. A separate questionnaire for neonatal deaths occurring before 28 days of life was used. Village reporters were 1–2 men or women selected from each village in the study area paid to report village births and deaths as they occurred. Beginning in September 2001 in Asembo and June 2002 in Gem, verbal autopsies were conducted using trained interviewers on all child deaths (<12 years old) at least one month from the date of death to respect mourning periods. The permanent identification numbers of all children were used to permit linking of clinical and demographic data. Using information from these questionnaires, a panel of three clinical officers (two years of post-secondary school medical training) independently assigned up to three causes of death; concurrence by at least two of the clinical officers was required to assign that diagnosis as a cause of death.

**Monitoring entomologic parameters of malaria transmission.** Monthly CDC light trap catches of *Anopheles* mosquitoes were conducted in Asembo beginning in May 2002. Each month, 10 individuals were randomly selected from the HDSS database and light traps were set in the selected house plus four neighboring houses for two sequential nights. Captured anophelines were tested for the circumsporozoite antigen using a standard enzyme-linked immunosorbent assay.<sup>11</sup> Although light-trap catches were not calibrated to human biting rate using the conversion factor determined by Lines and others,<sup>12</sup> the monthly entomologic inoculation rate (EIR) was calculated as the product of the average daily human biting rate, the annual sporozoite rate and the number of days in the month.

**Data management, quality control, and analysis.** Data forms were received at the CDC/KEMRI data management center for optical scanning. Scanned data were subject to logic checks to ensure compatibility with existing information. Inconsistent or illogical data were returned to the field for correction. Core demographic data were uploaded into the Household Registration System (HRS; Population Council, New York, NY), a relational database program developed specifically for HDSS data.

A random sub-sample of 600 compounds was selected each round for an independent quality control team to re-interview. Any discrepancies with core demographic data

were investigated and verified by a supervisor from the field headquarters.

All demographic rates were calculated with the assistance of the HRS. The crude death rate was the total number of deaths in the DSA in 2002 divided by the total person-time of observation. The neonatal mortality rate was the number of deaths in live-born children less than 28 days old divided by the number of live births in 2002; infant mortality rate (IMR) was the number of deaths among live-born children who died before their first birthday divided by the total number of births in 2002. The under-5 mortality rate (U5MR) was the number of children dying before their fifth birthday divided by the number of live births. 95% confidence intervals (CIs) were calculated for all mortality rates. Life expectancy was calculated from age-specific death rates, and the total fertility rate was calculated from age-specific fertility rates. All data presented are from 2002 unless otherwise noted.

**Ethical review and informed consent.** The HDSS was reviewed and approved by the institutional review boards of both CDC (Atlanta, GA) and KEMRI (Nairobi, Kenya). Informed written consent was obtained from compound heads for participation of their families in all aspects of the HDSS.

## RESULTS

**Population size, age, and sex composition.** In 2002, the total population of the DSA was 134,990 residing in 33,990 households and 20,560 compounds. Children less than 15 years of age comprised 45.4% of the total population and adults  $\geq 65$  years of age made up 6.0% (Figure 2). Overall males constituted approximately 46.6% of the total population.

**Mortality rates.** The crude death rate for the DSA was 23 per 1,000 person-years (p-y) (95% CI = 22–24), neonatal mortality was 23 per 1,000 live births (95% CI = 18–28), IMR was 125 per 1,000 live births (95% CI = 113–137), U5MR was 227 per 1,000 live births (95% CI = 211–243), and overall life expectancy at birth was 38 years (36 years for men and 39 for women). Compared with the rest of Kenya, the DSA population experienced significantly higher infant and adult mortality in the period under review. In 2002, the Kenya national crude death rate was 15 per 1,000 population.<sup>13</sup> In 2003, IMR was 79 per 1,000 live births, U5MR was 123 per 1,000 live births, and life expectancy at birth was 44 years.<sup>14</sup>

Mortality rates in the DSA began to increase at 15 years of age in female adolescents and at 20 years of age in men (Figure 3). Compared with mortality rates estimated for adolescents and adults 15–49 years of age in the 2003 Kenya Demographic and Health Survey,<sup>15</sup> mortality rates for adult women and men in the DSA were significantly higher.

**Cause of mortality.** The HDSS recorded 882 deaths of children less than 12 years of age; 778 (88.2%) of these deaths had verbal autopsy results. Of the 778 deaths recorded in the HDSS with verbal autopsy results, 37 (4.8%) were stillbirths, 76 (9.8%) were neonatal (0–28 days old) deaths, and 665 were deaths of children 1 month to <12 years of age. A cause of death could be ascribed to 75 (98.7%) neonatal deaths and 661 (99.4%) deaths in children 1 month to <12 years of age. Most (85.5%) of these deaths occurred at home with only 6.3% occurring at a health facility (an additional 10.9% died while traveling to or from a health facility). However, medical care during the terminal illness was sought by 85.8% of those

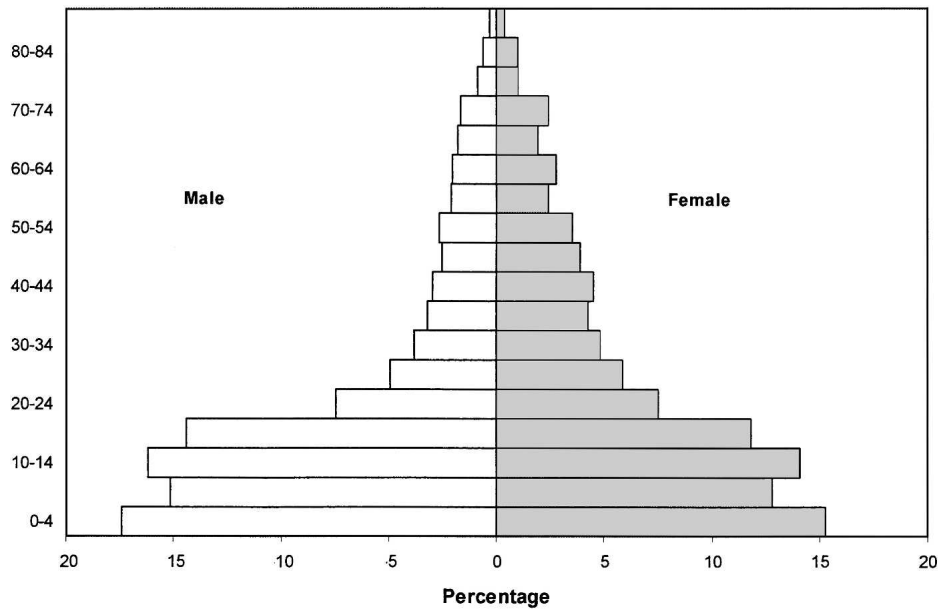


FIGURE 2. Distribution of the population of the demographic surveillance area by age (years) and sex in 2002.

who died. Sources of care during the terminal illness included clinics (37.1%), pharmacies (38.5%), hospitals (27.7%), and private physicians (19.0%).

Sepsis/meningitis was the most common cause of death among neonates (Table 1), whereas malaria was the most common cause of death among post-neonates (Table 2). Together, malaria and anemia were responsible for close to half of all deaths in post-neonates. Diarrhea/dehydration and pneumonia were more common causes of death among the youngest post-neonates, and malnutrition was more common among the oldest.

**Fertility.** The total fertility rate (TFR) for the population in the DSA was 5.3 live births. The national TFR for rural areas in Kenya in 2002 was estimated to be 5.6 live births.<sup>15</sup>

**Migration.** The overall out-migration rate was 117 per 1,000 p-y: women had a higher out-migration rate (127/1,000 p-y) than men (108/1,000 p-y) (Figure 4). The out-migration rate also varied by age with the peak for men (241/1,000 p-y) and women (315/1,000 p-y) occurring in the 20–24-year-old age group. There were also substantial age and sex differences in the in-migration rates. Women were more likely to in-migrate (167/1,000 p-y) than men (151/1,000 p-y). The peak in-migration rates for men (250/1,000 p-y) occurred in the 25–29-year-old age group, while the peak in-migration rate for women (367/1,000 p-y) occurred in the 20–24-year-old age group. Overall, in-migration exceeded out-migration for both men and women.

**Socioeconomic and educational status.** Socioeconomic in-

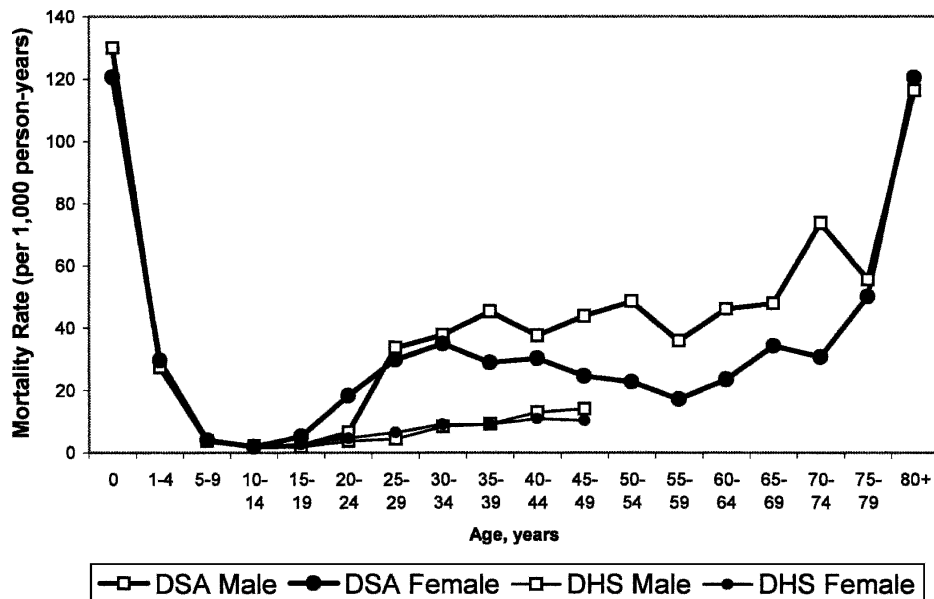


FIGURE 3. Age- and sex-specific mortality rates for the demographic surveillance area (DSA) in 2002 and Kenya as a whole (Demographic and Health Survey, 2003).<sup>13</sup>

TABLE 1

Cause of neonatal deaths (0–28 days) diagnosed through verbal autopsies western Kenya, 2002

Diagnosis	Overall (n = 75) n (%)
Sepsis/meningitis	32 (42.7)
Asphyxia	16 (21.3)
Prematurity/low birth weight	15 (20.0)
Anemia/hemolytic disease	6 (8.0)
Pneumonia	3 (4.0)
Diarrhea/dehydration	2 (2.7)
Sudden death	1 (1.3)

formation was available only for Asembo in 2002. Farming was the main source of income for 75.6% of all households. Despite the proximity to Lake Victoria, fishing was reported as an income source in only 1.6% of the households. Almost half of the households (49.9%) reported owning at least one radio, 46.1% owned at least one bicycle, and 51.3% reported owning at least one cow, goat, or sheep. Almost all households (94.4%) used firewood as the main source of cooking fuel; most (78.4%) drew their drinking water from unprotected sources such as the lake, ponds, and rivers.

In Asembo, a large proportion of children (21.2%) 6–14 years of age had never attended school. Of the residents  $\geq 15$  years of age, 67.2% had completed primary education, 17.0% had secondary education or higher, and the remainder (15.8%) had no education.

**Health facility surveillance.** We recorded 5,879 sick-child visits of DSA residents (<10 years old) to 14 health facilities in Asembo and Gem. The majority (51.3%) of children were between 1 and 5 years of age, 3.1% were <1 year of age, and 15.6% were between 5 and 9 years of age. The monthly number of visits varied throughout the year with the highest number following the long rainy season (Figure 5).

The most frequently recorded symptoms were fever (86.8%), cough (65.5%), vomiting (41.4%), and diarrhea (29.1%). When we used the IMCI algorithms as adapted for Kenya and modified for our study, diagnoses were available for 5,409 (92%) of the sick child visits. Malaria, alone or in combination with another illness, was the most frequent diagnosis (71.5%). Upper respiratory tract infections (25.7%) and diarrhea (10.1%) were the next most common diagnoses.

TABLE 2

Cause of death in children 1 month to &lt;12 years old diagnosed through verbal autopsies, western Kenya, 2002\*

Diagnoses	Age category			
	Overall (n = 661) n (%)	1 to 11 months (n = 320) n (%)	1 to 4 years (n = 298) n (%)	5 to 12 years (n = 43) n (%)
Malaria	191 (28.9)	98 (30.6)	80 (26.8)	13 (30.2)
Anemia	131 (19.8)	57 (17.8)	67 (22.5)	7 (16.3)
Diarrhea/dehydration	107 (16.2)	72 (22.5)	30 (10.1)	5 (11.6)
Pneumonia	105 (15.9)	54 (16.9)	48 (16.1)	3 (7.0)
Malnutrition	40 (6.1)	5 (1.6)	28 (9.4)	7 (16.3)
Sepsis/meningitis	35 (5.3)	20 (6.3)	13 (4.4)	2 (4.7)
HIV and TB	28 (4.2)	5 (1.6)	20 (6.7)	3 (7.0)
Injuries	8 (1.2)	4 (1.3)	4 (1.3)	0 (0.0)
Other	16 (2.4)	5 (1.6)	8 (2.7)	3 (7.0)

\* HIV = human immunodeficiency virus; TB = tuberculosis.

**Entomology and malaria transmission.** From May 2002 to April 2003, 868 anophelines were collected, 95.6% of which were identified as *Anopheles gambiae* s.l. and the remainder as *An. funestus*. The 12-month EIR was 7.2 infectious bites per person per year for this period. The monthly EIR varied with rainfall: the highest EIR occurred after the long rains (March–May) and the short rains (October–December).

## DISCUSSION

Collection of health and demographic data is particularly challenging in countries without established surveillance or registration systems, and yet these data are crucial for the development and evaluation of effective, targeted health interventions. Health and demographic surveillance systems, which monitor demographic and health indicators in a geographically defined population, have been developed to provide high quality data on a subset of the population with the intent to generalize results to other similar areas. An HDSS can be used as a surveillance system to monitor disease trends over time and as a platform from which to evaluate specific interventions.

The demographic data obtained through the HDSS in western Kenya draw attention to the excessively high mortality rates, particularly in children and young adults. Although high infant mortality rates are a common, although lamentable, feature of many developing countries, increased mortality rates in young adulthood are less common except in areas of conflict or high prevalence of HIV/AIDS. The demographic pattern of high infant and young adult mortality suggests that infectious diseases are significant causes of death. We began collecting information on adult causes of death through verbal autopsy methods in January 2003. When analysis of these data is completed, a more complete picture of the causes of mortality in young adulthood will be available.

Due to differences in data collection methods and database file structure, the mortality rates calculated from the HDSS are not directly comparable to those collected in the same area during a large randomized controlled trial to evaluate ITNs.<sup>6</sup> In that study, post-neonatal IMR (1–11 months) was 102.3 per 1,000 p-y in villages with ITNs and 133.3 per 1,000 p-y in villages without; these rates were calculated over a two-year period, did not include neonates, and used person-years in the denominator rather than live births. Therefore, although the IMR calculated as part of this HDSS (125 per 1,000 live births) is similar to the post-neonatal IMR during the ITN trial, no conclusions can be drawn from this comparison. An earlier study in Asembo prior to the ITN trial followed a cohort of children from birth and found a neonatal mortality rate of 32 per 1,000 live births (95% CI = 22–42), an IMR of 176 per 1,000 live births (95% CI = 155–196), and a U5MR of 257 per 1,000 live births (95% CI = 241–289).<sup>16</sup> Except for the neonatal mortality rate, the rates calculated from the HDSS in 2002 were all significantly lower than those reported for the cohort from 1992 to 1996. It is difficult to draw conclusions regarding differences in mortality rates collected using different methodologies; while some reduction in mortality can be expected due to the effect of ITNs,<sup>6</sup> differences in methodology and other temporal factors are likely to be the main cause for the apparent reduction in

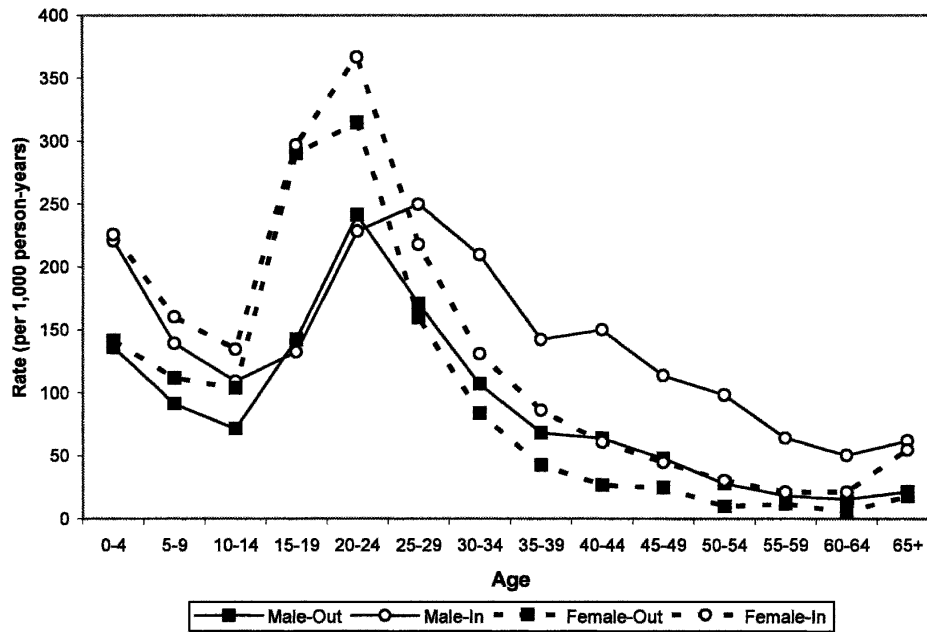


FIGURE 4. Age- and sex-specific migration rates in the demographic surveillance area, 2002.

mortality rates. In addition, it is important to note that the denominator for our mortality rate calculations (number of live births) was measured over a single year, which might distort rate calculations if birth rates fluctuate significantly between years.<sup>17</sup>

Among children, sick visits and verbal autopsy data support malaria, acute respiratory infections, and diarrhea as major causes of morbidity and mortality in children. Of note, sentinel antenatal clinic surveillance data from this area confirm HIV infection rates of 20–30% among pregnant women.<sup>18</sup> Assuming overall mother-to-child HIV transmission rates of 30–40%, approximately 10% of infants in this area are likely to be infected with HIV. Respiratory infections and diarrhea are common clinical syndromes associated with HIV infection in sub-Saharan Africa.<sup>19</sup> Although rarely reported as an outpatient diagnosis or cause of death, HIV/AIDS most probably contributes substantially to the local burden of pediatric morbidity and mortality.

Preliminary results from a community-based cross-sectional survey that drew a sampling frame from the HDSS confirm that the prevalence of HIV infection among the general young-adult population was 21% among women and 11% among men 13–34 years of age (Amornkul P and others, unpublished data). In a Ugandan population with an HIV seroprevalence of 8%, the mortality fraction attributable to HIV was greater than 70% among women 20–44 years of age and men 25–44 years of age.<sup>20</sup> In our DSA, where HIV prevalence is much higher, an overwhelming proportion of adult mortality is likely related to HIV. Verbal autopsies for adult deaths in the DSA began in 2003 and may further elucidate the specific syndromes associated with young adult mortality.

Although diagnosis of malaria at health facilities or through verbal autopsy tends toward low sensitivity and specificity,<sup>21</sup> these data still suggest that malaria is a substantial contributor to pediatric illness and death. Given the sustained 90% reduction in malaria transmission, sustained reductions in infant

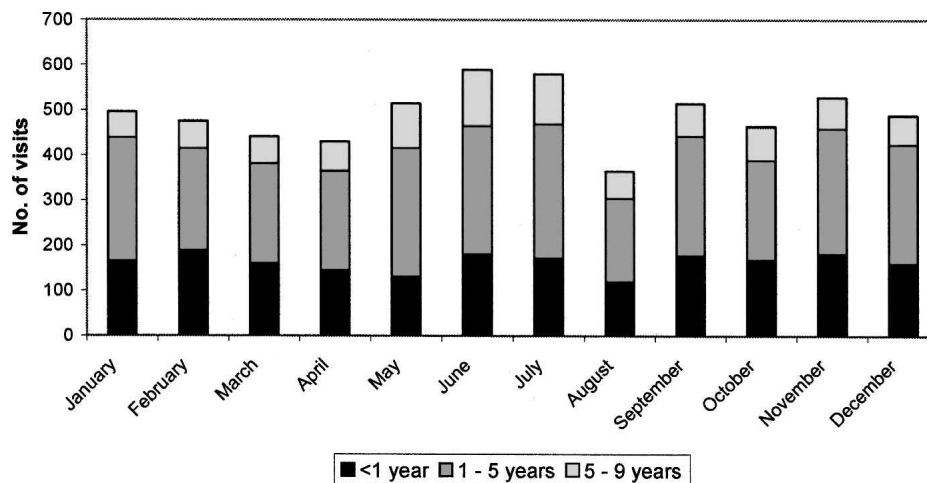


FIGURE 5. Numbers of sick child visits to outpatient facilities in the demographic surveillance area by month and age, 2002.

mortality, and a low entomologic inoculation rate of seven infectious bites per person per year as a result of the continued use of ITNs,<sup>5</sup> such a finding is a reminder of the robustness of malaria transmission; other researchers have suggested that significant morbidity and mortality continues to occur until malaria transmission decreases below one infectious bite per year.<sup>22</sup> Given the high, continued coverage of ITNs in this area, the HDSS could provide important data to evaluate the impact of integrated malaria control (ITNs in concert with other transmission reduction methods such as larval control, improved case management, and prevention of malaria in pregnancy) in decreasing childhood morbidity and mortality from malaria.

Migration into and out of the DSA, as well as within the DSA, is high, with 117 of every 1,000 people leaving the DSA each year. Among residents 20–24 years of age, almost one-fourth of the men and one-third of the women out-migrate each year. Although the motives for movement into and out of the DSA are still being investigated, seeking employment and marriage appear to be important reasons (Adazu K and others, unpublished data). It is not yet clear what proportion of those who leave eventually return to the area, nor have we yet completed analysis of the demographic and health characteristics of the migrants. Further collection and analysis of migration data will allow us to more accurately account for potential loss to follow-up and biases of studies conducted in the DSA.

The HDSS described in this report is an integrated computer and field operations system with one of the larger populations under health and demographic surveillance in the world ([www.indepth-network.org](http://www.indepth-network.org)). This enormous undertaking is not without significant challenges, particularly in ensuring and verifying that quality data are collected. With more than 30 field staff collecting household data door-to-door, supervision and data verification are imperative. Extensive trainings are conducted before each round, and regular weekly meetings ensure that field staff understand and follow standardized procedures. Additional quality control procedures such as repeat interviews and intentionally giving field staff false information that must be detected and corrected are also useful techniques to ensure quality data.

An HDSS of this magnitude would not be possible without sophisticated computer systems to manage data and ensure compatibility of information across multiple tables. The HRS system developed by the population council is well-designed and used in most of the HDSS worldwide.<sup>23</sup> Information is entered into a relational database after multiple logic and validity tests, and the system will not permit entry of inconsistent data. Traditionally, the HRS works from hand-entered data with one record entered at a time. Given the large amount of data processing required to monitor a population of 135,000, we modified this system to allow batch processing of data through scanned data forms. Although scanning allows data to be captured at least an order of magnitude faster than hand entry, the programming required to make batch processing compatible with HRS has been challenging. It is hoped that newer versions of HRS will allow maximal usage of the more sophisticated data entry methods currently available.

Although an HDSS can be a powerful tool for identifying health problems and evaluating interventions to reduce morbidity and mortality, the minimal cost of running and main-

taining a basic demographic surveillance system has been estimated to be \$0.75 per person under surveillance per round of data collection.<sup>24</sup> Because the value of an HDSS comes primarily from long-term sequential data collection, cost may be a substantial challenge to organizations interested in running an HDSS. An additional challenge is the potential loss of representativeness of the DSA to the population and area to which the data are to be extrapolated. Improvements in infrastructure and health facility services are likely to accompany the establishment of an HDSS, thereby improving access to health services and altering the pre-existing relationships between behavior, the environment, and their impact on the incidence of disease. Any public health intervention subsequently applied to the population will further decrease the representativeness of the DSA. However, this potential loss of generalizability is usually more than offset by the value of the information collected and the accompanying public health benefits to the community.

It has been recently noted that HDSS sentinel sites may be a key method for collecting the data necessary to evaluate the impact of international public health programs such as Roll Back Malaria.<sup>24</sup> The data generated by the HDSS in western Kenya clearly identify an urgent and considerable need for additional interventions in the area against infectious diseases such as malaria and HIV. The value of the HDSS lies in the ability to identify significant public health issues, as well as to provide the data and infrastructure required to evaluate the impact of interventions.

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