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Health & Demographic Surveillance System Profile

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Profile: The Rusinga Health and Demographic Surveillance System, Western Kenya

Tobias Homan,[1]* Aurelio di Pasquale,[2,3] Kelvin Onoka,[4] Ibrahim Kiche,[4] Alexandra Hiscox,[1] Collins Mweresa,[4] Wolfgang R Mukabana,[5] Daniel Masiga,[4] Willem Takken[1] and Nicolas Maire[2,3]

[1]Laboratory of Entomology, Wageningen University and Research Centre, Wageningen, The Netherlands, [2]Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Basel, Switzerland, [3]University of Basel, Basel, Switzerland, [4]Department of Medical Entomology, International Centre of Insect Physiology and Ecology, Nairobi, Kenya and [5]School of Biological Sciences, University of Nairobi, Nairobi, Kenya

*Corresponding author. Laboratory of Entomology, Wageningen University and Research Centre, Wageningen, The Netherlands. E-mail: tobiassolarmal@gmail.com

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Abstract

The health and demographic surveillance system on Rusinga Island, Western Kenya, was initiated in 2012 to facilitate a malaria intervention trial: the SolarMal project. The project aims to eliminate malaria from Rusinga Island using the nationwide adopted strategy for malaria control (insecticide-treated bed nets and case management) augmented with mass trapping of anopheline mosquitoes. The main purpose of the health and demographic surveillance is to measure the effectiveness of the trial on clinical malaria incidence, and to monitor demographic, environmental and malaria-related data variables. At the end of 2014, the 44 km^2 island had a population of approximately 25 000 individuals living in 8746 residential structures. Three times per year, all individuals are followed up and surveyed for clinical malaria. Following each round of surveillance, a randomly selected cross-section of the population is subject to a rapid diagnostic test to measure malaria. Additionally, extensive monitoring of malaria vectors is performed. Data collection and management are conducted using the OpenHDS platform, with tablet computers and applications with advanced software connected to a centralized database. Besides the general demographic information, other health-related data are collected which can be used to facilitate a range of other studies within and outside the current project. Access to the core dataset can be obtained on request from the authors.

Key words: Health and demographic surveillance, Rusinga Island, Malaria, OpenHDS

Key messages

- The Rusinga HDSS covers an island in Lake Victoria, Kenya, characterized by high seasonal migration rates.
- The Rusinga HDSS facilitates in-depth studies into the transmission of malaria. A trans-disciplinary intervention trial aiming for the elimination of malaria transmission is the core driver behind this surveillance.
- The HDSS uses the OpenHDS system which provides a cost-effective way to collect, store and manage data, as well as to safeguard quality assurance.
- The HDSS provides a robust foundation to conduct not only malaria research; future collaboration with local and international institutes will enable researchers to combine resources and interests.

Why was the HDSS set up?

A malaria intervention study based on removal trapping of anopheline mosquitoes in addition to the Roll Back Malaria (RBM) control strategy[1] was initiated on Rusinga Island, Western Kenya, in 2012. Mosquito traps baited with a synthetic lure that mimics human odour are placed at the household level to reduce mosquito population density and, as a consequence, lower the intensity of malaria transmission.[2] Traps are powered by solar energy, which is also used to provide electric light and mobile phone charging points for the household members. The combination of solar energy with malaria control led to the project being named SolarMal. A health and demographic surveillance system (HDSS) was established to facilitate continued monitoring of demographic, and particularly malaria-related, variables. In addition, the complex roll-out logistics of the SolarMal intervention required accurate and up-to-date information about the population and their housing. Although the main objective of the HDSS is to measure the effectiveness of the vector control intervention on health and population outcomes, the collected demographic and malaria-specific data may be used for validation of epidemiological models as well as entomological and parasitological research. The most prominent objectives facilitated by the HDSS are:

i. longitudinal monitoring of demographic dynamics to provide a robust framework for research;
ii. studying the epidemiology of malaria;
iii. analysing the effect of the SolarMal intervention on malaria prevalence, transmission and mosquito abundance;
iv. measuring the interaction between the intervention and existing approaches to malaria control (RBM), and environmental and socio-economic variables.

The Rusinga HDSS collects demographic information, malaria related variables and other information on factors that are likely to influence malaria epidemiology and malaria mosquito ecology. The HDSS provides different disciplines within the project with an up-to-date population database. The entomological and parasitological experimental designs, as well as the logistics for rolling out the intervention, rely on the continued updating of the study population (W.T., personal communication.). An important component of SolarMal is the inclusion of sociological studies, and the population database enables social scientists to conduct targeted sociological research. Since 2012, an extensive baseline survey and eight subsequent follow-up rounds have been conducted. The roll-out of the intervention traps started in June 2013 and was completed in May 2015, at that point covering all households on the island.

Where is the HDSS area?

Homa Bay County is located in Western Kenya at Lake Victoria, within the former province of Nyanza, exposed to the south of the Winam Gulf. Rusinga Island is situated between latitudes 0°21′ and 0°26′ south, and longitudes 34°13′ and 34°07′ east (Figure 1). A causeway connects the island with the mainland. Rusinga Island stretches over 44 km^2 with an elevation between 1100 m and 1300 m above sea level. Mean daily temperatures vary from 16 to 34 degrees Celsius with higher temperatures in the dry seasons that occur between June and October and late December and February. Seasonality in precipitation is traditionally experienced as one long rainy season ranging from March into May (average of 198 mm per month in the period 2012–14) and a short rainy season from October to early December (average of 132 mm per month). The local administration consists of two chiefs, each governing one part of the island: Rusinga East and Rusinga West. The local authority divided the island into eight subzones containing a total of 36 villages and about 10 beach communities (Figure 2). For the purpose of the SolarMal trial and to measure the impact of the intervention most effectively, the island was divided into nine metaclusters each consisting of nine clusters. Each cluster comprises 50 or 51 households. The HDSS operates from the International Centre of Insect Physiology and Ecology (*icipe*) at the village of Mbita Point at the mainland side of the causeway.

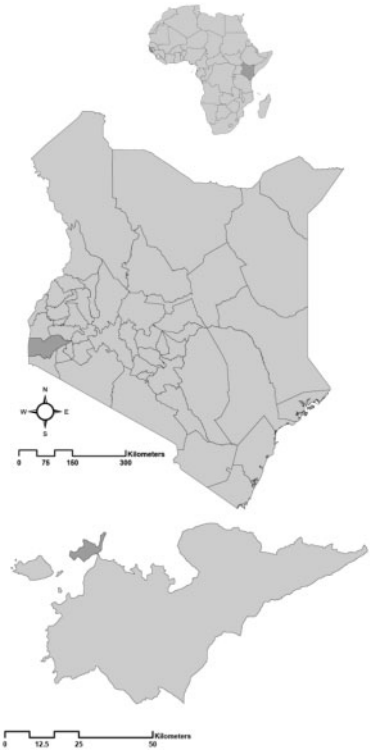

Figure 1. The upper figure shows Africa with Kenya highlighted dark grey in the middle, Kenya with Homa Bay County highlighted; lower figure depicts Homa Bay County with Rusinga Island in dark grey.

Who is covered by the HDSS and how often have they been followed up?

The population of Rusinga Island belongs to the Luo ethnic group and Dho Luo is the main spoken language. The national languages (English and Swahili) are also used. Fishing and farming are the principal occupations, with people typically harvesting millet, sorghum and maize and fishing tilapia and Nile perch. Christianity is the predominant religion (84%) in this area; the Muslim community (12%) forms a minority.

Most houses on the island are made of mud or cement walls with iron sheet roofs. Connection to the electrical grid is rare and there is little to no supply of piped potable water. There are several health facilities on the island; one governmental health centre, one government clinic, two private clinics and one drug dispensary. Non-governmental organizations have established a further two clinics. A district hospital is found at Mbita Point village.

All members of the population are visited three times a year. By August 2015, each location had been visited eight times, including the baseline enumeration. With the baseline conducted in 2012, and the latest update round completed in mid 2015, currently eight rounds of surveillance have been carried out in the course of the first two complete years of health and demographic surveillance. During this period, a total of 33 283 people were registered in the database, with residences divided over 8746 houses and belonging to 5457 households. The recorded number of people living on Rusinga island in mid 2015 was 24 643.

The leading causes of death in this area are HIV/AIDS related, with an HIV prevalence of 26% (Ministry of Health Kenya: *HIV Estimates*, 2014). Malaria is hyper-endemic and existent in this region throughout the year, with peaks in transmission at the end and just after the rainy seasons when *Plasmodium* parasite prevalence of around 30% is reported (*World Health Organization* Country Profile 2014: Kenya, Malaria). The population is characterized by a seasonal influx of labourers searching for jobs in the fishing industry. Temporary in- and out-migrations are distinguished from permanent migration within the Rusinga HDSS. Households are recorded following the Luo description of a *dhala*: any set of houses that share a head of household and/or are economically dependent.

The age distribution of Rusinga has a typical East African profile. Baseline studies (2012) and 2 years of data collection (2013 and 2014) demonstrate that approximately 40% of the population is under the age of 25 and almost 90% of the population is under the age of 45 (Figure 3). All consenting individuals living on the island are subject to the HDSS to monitor demographic and malaria-related variables.

The HDSS, the local population and the intervention programme are strongly connected by means of a community advisory board (CAB) which, together with project staff, regularly evaluates the progress of the project and matters encountered during fieldwork.

What has been measured and how have the HDSS databases been constructed?

The baseline enumeration was carried out from June to September 2012, recording all households, houses and individuals on the island. All households were provided with an odour-baited malaria mosquito trap to attract and kill mosquitoes, using a stepped-wedge cluster randomized trial design. The hypothesis is that mass trapping of malaria

Box 1.

Content of questionnaires administered during the census and each follow-up survey. *Data are collected only when a new subject is enumerated. **Indicates that the questionnaire is administered for all new residential structures, as well as every 2nd year for all registered residential structures

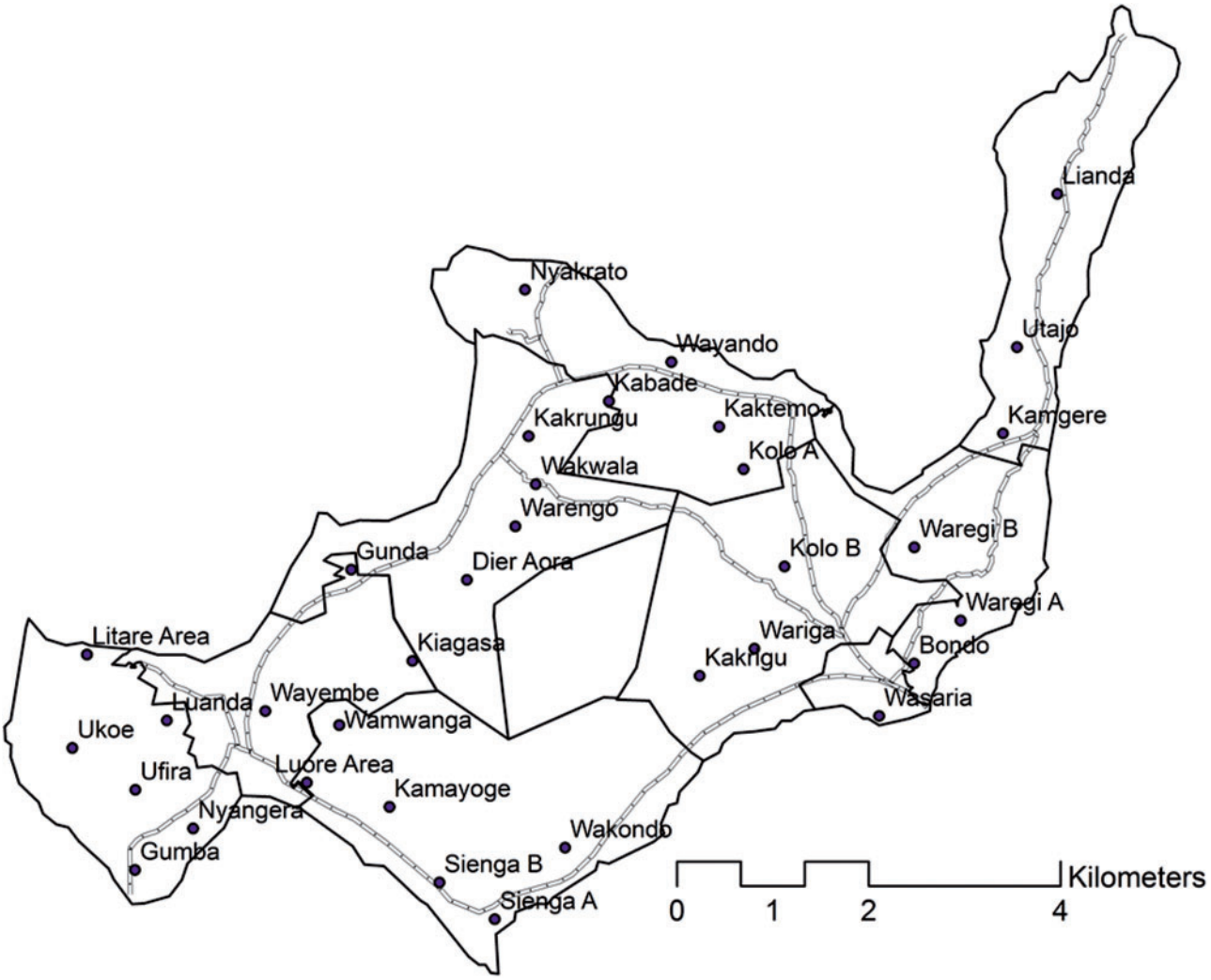

Figure 2. Rusinga Island with an uninhabited hill in the centre. Boundaries of metaclusters (thick black lines); villages (indicated with dots); roads (dashed lines).

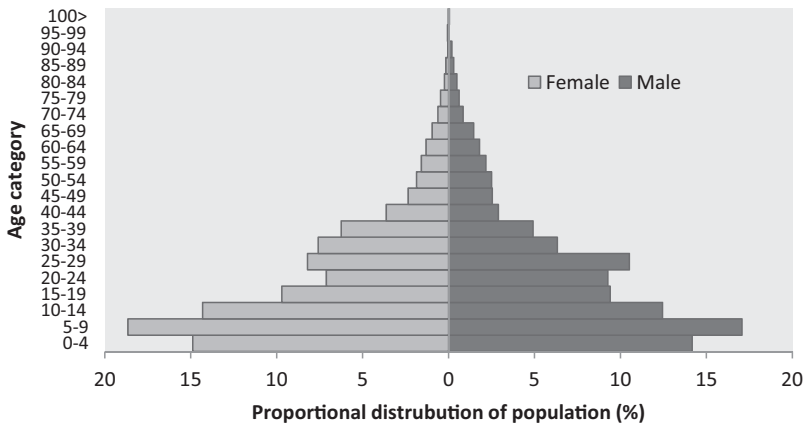

Figure 3. Population pyramid of Rusinga Island with the percentage of people illustrated per age category.

vectors leads to reduced malaria transmission, incidence and prevalence. All structures with residents were mapped using the Global Positioning System (GPS) function on a tablet computer. Households, houses and individuals are assigned unique identification codes. All inhabitants were requested to provide their full name, sex, date of birth, main occupation and their relation to parents and the head of household. During the census round, fieldworkers

Visit form: scanning bar code on house to confirm follow-up visit and set date of interview

Household*: new household ID, number of houses in the household, name and ID of household head

House*: new house ID, longitude and latitude, household head ID and name, photo of the house, number of individuals

Individual*: new individual ID, names, date of birth, sex, level of education, occupation, relation to the household head

Household characteristics:** ownership of dwelling, no. of rooms, no. of bedrooms, location of kitchen, source of electricity, source of light, agricultural land ownership, wall construction, floor construction, roof construction, whether eaves are screened, whether IRS[3] has been applied during the past year, bed nets reported, bed nets observed, no. of bed nets, when were bed nets obtained, condition of bed nets, other mosquito control methods used by household members

Death registration: individual ID, name, date of death, outcome of verbal autopsy, verbal autopsy performed by, cause of death, place of death

Pregnancy observation: mother ID, no. of months pregnant, attended health facility during pregnancy, received TT-injection,[1] other medicines, estimated date of birth, woman's first pregnancy

Pregnancy outcome: delivery outcome, name of child, date of birth of child, sex, creation of new individual ID, house ID, household ID, link to parents' ID

Migration out: individual ID, house ID, household ID, date of migration, within Rusinga, to which village/zone, out of Rusinga, reason for migration

Migration in: previously registered by SolarMal, village/zone, new individual ID, names, date of birth, sex, highest level of education, primary occupation, relationship to the household, house ID, household ID, date of migration, reason for migration, moved from

Individual health: individual ID, any illness during the past 2 weeks, current fever reported, under malaria treatment at the time of the visit, temperature (if indicated illness), RDT[2] result (tested if $> 37.3°C$), any respiratory symptoms, medical attention, what medical attention, drugs against fever, which drugs

[1]TT injection is a tetanus vaccine which can be injected during pregnancy to prevent neonatal tetanus.
[2]RDT is a rapid diagnostic test performed to promptly detect evidence of malaria parasites in the blood.
[3]IRS is indoor residual spraying of insecticides on walls.

(FWs) were assisted in locating all houses and individuals by a local community-based organization, the Rusinga Malaria Project (RMP), which has been involved in malaria control practices on the island for over a decade. From January 2013, collection and updating of demographic and malaria and health-related data started. The HDSS operates by house-to-house interviews, visiting on average 120 houses per day, equally distributed across the nine meta-clusters. Interviews take approximately 30 min per house depending on the number of people living there. Each HDSS round is completed in approximately 3 months. During household visits, observed pregnancies, new births, deaths and migrations which have occurred since the previous visit are recorded and updated (Box 1). Clinical malaria is recorded during HDSS rounds, based on fever recalls and a conditional rapid diagnostic test, and at the end of each round the team performs blood collections on a random sample of the population. Digital questionnaires on demography are consistent with the HDSS questionnaire format of the principal HDSS association globally, the INDEPTH network.[3,4] These standardized questionnaire formats are widely used in East Africa, including Kenya, and therefore apply well to our study site. The HDSS uses tablet computers and the OpenHDS system, which allows for rapid centralization of the data without need for processing paper forms. This reduces data management overheads and allows for rigorous and timely quality control. A detailed description of this system can be found elsewhere.[5] The HDSS team consists of 10 FWs, a fieldworker manager (FWM) and a data manager. The local team has access to a senior software manager. A server running the OpenHDS software is hosted at the *icipe* field station in Mbita.

OpenHDS, a software platform that is based on a centralized database, a web application for data management,[6] is linked to a tablet computer-based mobile component which allows digitization of data at the point of capture, and wireless synchronization to the central data store based on the Open Data Kit (ODK) platform.[7,8]

Samsung Galaxy Tab 2 tablet computers were used from the start for data collection, and upgraded after years to the successor Galaxy Tab 3. Data entry errors are minimized through basic range checks and the integration of different questionnaires through system-wide IDs in a guided workflow. The ODK and OpenHDS platforms allow the FWM and data manager to use a range of data cleaning options, many of which are guided by reports generated automatically on a nightly basis. This process

enables scientists to use the clean data for analysis with minimal delay. Furthermore, to monitor the performance of FWs, a web-based tool was developed that monitors progress of the work FWs conduct over time, allowing the project to optimize the quality and effectiveness of data collection. Finally, the data of all sub-disciplines of SolarMal are connected to each other by one of the three levels of unique codes and are kept in a MySQL relational database. Calculation of demographic rates and further quality assurance is conducted using the iShare2 software [http://www.indepth-ishare.org].

Key findings

The demographic data collected during the census survey in 2012 up to May 2015 is the basis for Table 1. Reported demographic figures are calculated for the complete years of 2013 and 2014. To place the reported rates in context, the same measurements calculated by other HDSSs operating close to Rusinga in the years 2007 and 2010 are also reported in Table 1. Kaneko *et al.*[9] published demographic information on the basis of the Mbita HDSS covering Rusinga and neighbouring areas in 2011. An HDSS at Kisian and surrounding areas operated by the KEMRI/CDC some 150 km north-east of Rusinga reported rates for 2007.[10] In calculating person-time at risk, we defined residents as those who stayed in the HDSS area 60 days (2 months) or longer. Registered individuals who stayed less than 60 days during a year were removed for the calculation of total person-years. Table 1 shows the key demographic indicators of the Rusinga HDSS for the years 2013 and 2014. The total population that was registered in the database by the end of 2013 was 29 206, and the total contributed person-years in 2013 was 24 350. The total number of individuals enumerated by the end of 2014 was 33 283. By December 2014, the HDSS registered a total of 8746 residential structures divided over 5457 households. The sex ratio is skewed towards females, with 91 men for every 100 women. The average population density was 553 (2013) and 577 (2014) person-years per km^2 calculated on the basis of 44 km^2 of landmass. However, as shown in Figure 4, the population is not evenly distributed and there are densely populated fishing beaches and a large village in the south east; the hill in the centre of the island is uninhabited. The total fertility rate (TFR) is calculated as the average number of children that would be born per woman if all women lived to the end of their childbearing years (15–49 years), yielding a TFR 2.1 for both years.

The crude birth rate (CBR) and crude death rate (CDR) are presented as the number of live births or deaths per 1000 residents. We found a CBR of 18.7 (2013) and 18.5

Table 1. Key demographic indicators over the years 2013 and 2014 on Rusinga Island; compared with indicators reported during the Mbita HDSS in 2010 and the KEMRI HDSS in 2007

Indicator	Unit	Rusinga 2013	Rusinga 2014	Mbita 2010	KEMRI 2007
Total population visited	Total number of individuals enumerated	29206	33283	–	–
Total houses visited	Total number of houses enumerated	8141	8746	–	–
Total households visited	Total number of households enumerated	4948	5457	–	–
Male : female ratio	Proportions of sexes	91	91	91.2	90.1
Population density	Average number of people per km^2	553	577	–	–
Total fertility rate	Average number of live children per woman	2.1	2.1	3.7	5.3
Crude birth rate	Births per 1000 person-years	18.7	18.5	29.7	36.8
Crude death rate	Deaths per 1000 person-years	6.3	5.8	9.1	15.9
Life expectancy at birth (male)	Expected years to live at birth	66.9	68	57.5	46.5
Life expectancy at birth (female)	LE at birth	68.8	68.6	61.0	46.5
Infant mortality ratio (< 1 year of age)	Infant deaths per 1000 live births	17	11	14.1	76
Child mortality rate (1–4 years)	Child deaths per 1000 person-years	7.4	6.8	–	16.5
Child mortality ratio (1–4 years of age)	Deaths between ages 1 and 5 years per 1000 children	29	27	–	58.8
Under-five mortality rate	Under-five deaths per 1000 person-years	9.7	7.5	–	29.5
Under-five mortality ratio	Under-five deaths per 1000 live births	45	37	91.5	167.0
Crude in-migration rate (external)	In-migrations per 1000 person-years	(*)	127.9	64.1	115
Crude out-migration rate (external)	Out-migrations per 1000 person-years	164.6	148.9	86.2	111
Malaria prevalence	Percentage of population with a positive RDT	27.1	28.1	–	–
Malaria mosquito abundance	Average number of mosquitoes per trap night	0.30	0.21		

*No in-migration rates reported for 2013. Catch-up enumerations in the first months of 2013 enumerated households which were missed in the baseline survey, and could therefore not reliably be distinguished from in-migration events.

(2014), and CDRs of 6.3 and 5.8 were determined for 2013 and 2014. Compared with the HDSS of KEMRI/CDC at Kisian, both the Mbita and the Rusinga HDSS report a lower CDR. The life expectancy (LE) at birth for females and males is calculated as the total number of person-years lived in all age intervals of the static population, divided by the number of alive individuals at the start of every 5-year age interval. For males in 2014, the LE at birth was 68 years; for females the LE at birth was 68.6 years.

The infant mortality ratio was 17 in 2013 and 11 in 2014 [number of infant deaths (aged <1 year) per 1000 live births]. As the ratio is based on a very small number of deaths it is likely there is a strong effect of stochasticity on these rates. The child mortality ratio in both years was 27 (number of deaths between 1 and 4 years per 1000 children) and the under-five mortality ratios, presented as the number of deaths in that age category per 1000 live births, were 45 and 37.

Calculation of all mortality rates, as well as the CDRs, yield lower rates and ratios than the KEMRI/CDC HDSS. Our findings are comparable to the results of the Mbita HDSS.[9] Unlike the Mbita and the Rusinga HDSSs, the KEMRI/CDC HDSS worked together with at least two health clinics in recording deaths, which most likely resulted in a more sensitive death registration system. In addition, it is common in Luo culture to return to the place of birth at the time of death. As there are many working immigrants residing on Rusinga Island, this could explain the lower number of recorded deaths taking place on the island.

The in-migration and out-migration rates are also calculated using person-years. The analysis of the migration rates for the year 2014 shows a crude in-migration rate of 12.9 per 1000 person-years and a crude out-migration rate of 148.9.[10]

Table 2 summarizes characteristics of 6640 inhabited houses where information about the house was collected. These results are comparable to other HDSSs in Western Kenya, such as Asembo and Gem[10] and around Mbita.[9,11] On Rusinga, a typical house is made from mud walls, a roof of iron sheeting and a cement floor. Most houses have bed nets, but are not protected against mosquitoes flying into the house through the open eaves.[12] Only a fraction of the population has access to the electrical grid and the

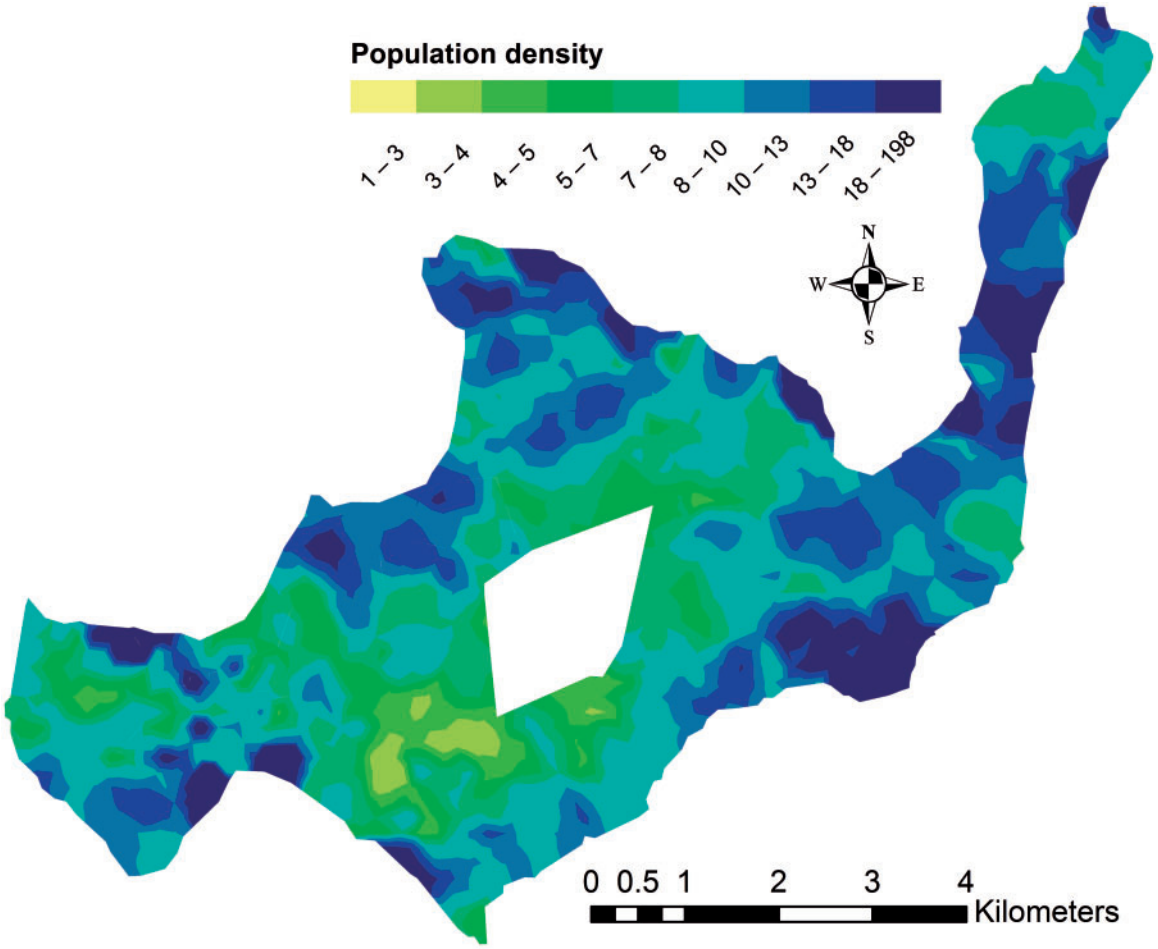

Figure 4. Distribution of population density on Rusinga Island for the year 2013.

Figure 5. (a and b) Typical environment of a fishing beach on Rusinga Island.

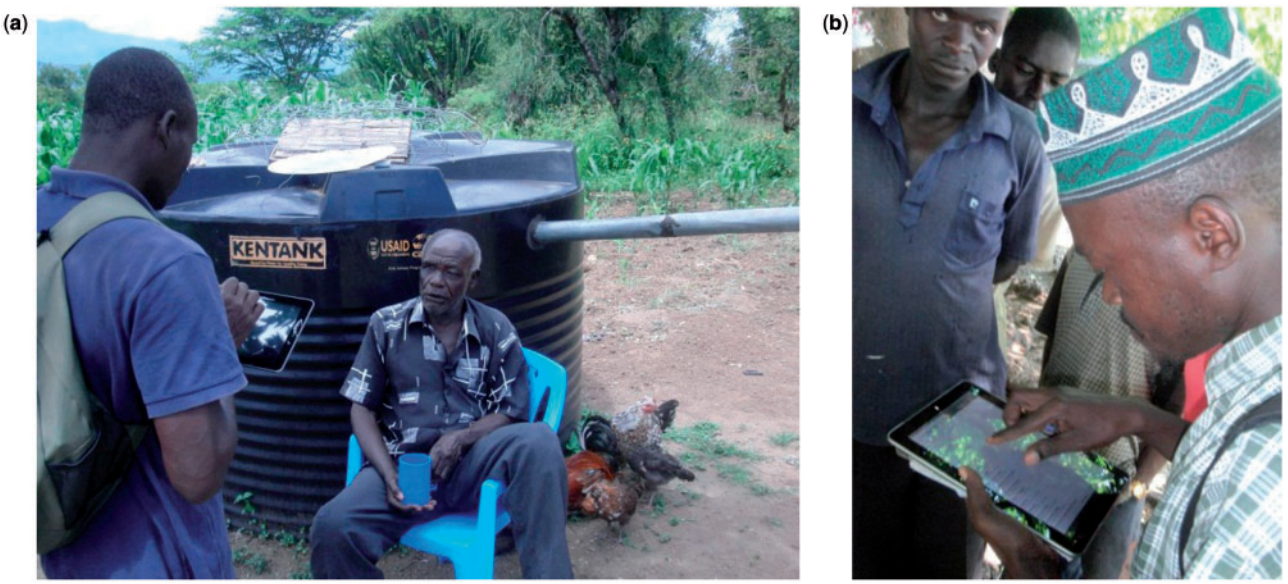

Figure 6. (a and b) The Rusinga HDSS in practice, collecting data on a computer tablet with the ODK and OpenHDS platform.

main sources of indoor light were kerosene lamps at the time when the SolarMal intervention was rolled out.

Finally, the average the island-wide malaria prevalence and the average number of malaria mosquitoes caught per trapping night for the rainy seasons in 2013 and 2014 are reported in Table 1. The malaria prevalence is established on basis of a cross-sectional survey of 10% randomly selected people tested with an RDT. Malaria mosquito abundance is established on basis of three surveys of mosquito monitoring at 80 randomly selected households. Ignoring intervention arms, malaria prevalence did not differ much island-wide between both years, with 27.1% and 28.1% prevalence, respectively. However, we found a difference in malaria mosquito abundance with an average of 0.30 mosquitoes per trapping night in 2013 versus 0.21 in 2014.

Future analysis plan

The HDSS data are a valuable resource when studying the parasitological, entomological and sociological[13] aspects of the malaria interventions. For example, the spatial and temporal distribution of malaria and its vectors, in combination with environmental data, will be used to measure the effect of the introduction of odour-baited traps in combination with pre-existing widespread use of insecticide-treated bed nets (ITNs) and case management. Other

Table 2. Summary of house information collected over the year 2013

Indicator	No.	%	Indicator	No.	%
I) Ownership of house			VIII) Wall structure		
Owner	4955	74.6	Wood and mud	4327	65.2
Rent	1327	20.0	Bricks and/or blocks	1161	17.5
Other	358	5.4	Mud and cement	489	7.4
II) Number of rooms			Iron and sheet	565	8.5
1	1725	26.0	Other	98	1.4
2	2090	31.5	IX) Floor structure		
3	2142	32.3	Carpet	3694	55.6
4	417	6.3	Cement	2480	37.3
5	152	2.3	Earth, dung or sand	442	6.7
<5	114	2.0	Other	24	0.4
III) Location of kitchen			X) Roof structure		
Outside the house	2217	33.4	Iron sheets	6559	98.8
Main living area indoors	1413	21.3	Thatch	52	0.8
Separate kitchen building	1271	19.1	Asbestos	25	0.4
Separate room in the house	209	3.1	Other	4	0.1
In another house	1065	16.0	XI) Screened eaves		
Daytime outside; night inside	465	7.0	Yes	441	6.6
IV) Source of electricity			No	6199	93.4
None	6137	92.4	XII)IRS sprayed within 12 months before visit		
Connected to power grid	162	2.4	Yes	2709	40.8
Generator	58	0.9	No	3604	54.3
Battery	65	1.0	Unknown	327	4.9
Solar power	218	3.3	XIII) Bed nets reported		
V) Source of light			Yes	6215	93.6
Kerosene-powered	6356	93.0	No	425	6.4
Candlelight	16	0.2	XIV) Bed nets observed		
Electric light	392	5.7	Yes	4830	72.7
None/other	64	0.9	No	1810	27.3
VI) Level of education of head household			XVI) Condition of nets		
Pre school	76	1.1	Undamaged or new	3929	59.2
Primary	4078	61.4	At least one breach	2301	34.7
Secondary	1814	27.3	Unknown	410	6.2
Higher	459	6.9	XVII) Other mosquito control		
Non-standard	174	2.6	Burning a mosquito coil	125	1.8
Unknown	39	0.06	None	6257	94.3
VII) Land for farming			Other	261	3.9
Yes	1480	22.3	Total	6640	100.0
No	5160	77.7			

topics being studied are the emergence of malaria hotspots, models of the interaction between vector presences, and the spatial analysis of malaria. Data from the HDSS and the trial are used to parameterize mathematical models of malaria. However, this HDSS provides a platform not only to study and analyse malaria-related outcomes within the SolarMal project, but also for other public health-related research on Rusinga Island. From 2016 we establish prolonged monitoring of the intervention, and we strive to introduce eave-screening to enhance the possible effect of odour-baited traps on malaria transmission. Furthermore, we will introduce verbal autopsy and various other standardized types of health-related data. Knowledge, resources and objectives will be combined to equip the Rusinga HDSS with a broader scope of health-related subjects after the SolarMal project comes to an end.

What are the main strengths and weaknesses of the Rusinga HDSS?

A major strength of this HDSS is the innovative process for data collection in the field (OpenHDS and ODK) using tablet computers, which simplifies the management of system-wide unique identifiers for individuals and houses and their linking to health- or intervention-related data. Point-of-capture digitization and the client-server architecture of

the data management system save time and money in terms of entering, accumulating, managing and processing data compared with its predecessor Household Registration System 2.[14] Data quality is of great importance in an HDSS and, due to a digital data collection organization rather than a paper-based system, the error rate of the collected data in the Rusinga HDSS is well below 1% according the quality metrics of iShare2.

A weakness of the pioneering system in this phase is that support of a skilled software developer and data manager is required. Other applications with web interfaces that make this HDSS distinct are the real-time monitoring of demographic and health-related events, keeping track of the performance of FWs and the use of geographical information systems to assist in precise navigation, and spatial research and analysis. Data can thus immediately be processed and used to facilitate all scientific disciplines in the project. Another strength of the Rusinga HDSS is the fact that it works closely together with the interest groups in the study area. By communicating with community health workers and delegates from different segments on the island, a sustaining cooperation and interaction have been created. In the future it should be possible to expand the system to capture information on other health outcomes. A priority and an important improvement for the near future is the integration of verbal autopsies as part of the demographic surveillance.

Data sharing and collaboration

After the main publications of the effect of the SolarMal intervention are published, all basic data and descriptive maps are available through SolarMal project management. Individual- and household-level data relating to demography or malaria for the purpose of new analysis are open to scientists in collaboration with Wageningen University. Please contact Tobias Homan [tobiassolarmal@gmail.com] for any enquiries and queries regarding datasets of the Rusinga HDSS.

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Conflict of interest: None declared.

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