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I.N.E.D | *Population*

2008/3 - Vol. 63
pages 443-467

ISSN 0032-4663

Available online at:

http://www.cairn-int.info/journal-population-2008-3-page-443.htm

How to cite this article:

Géraldine Duthé "Recrudescence du paludisme au Sénégal : la mesure de la mortalité palustre à Mlomp", *Population*, 2008/3 Vol. 63, p. 443-467. DOI : 10.3917/popu.803.0505

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Malaria Resurgence in Senegal: Measuring Malaria Mortality in Mlomp

The problem of malaria and its resurgence in Africa is an issue of critical concern, calling for in-depth research and urgent action. Using consolidated data from verbal autopsies and parasitological tests, Géraldine Duthé *studies trends in malaria mortality (1985-2003) in a rural community of Senegal. These detailed cause-of-death data offer an original source of information, rarely available in Africa, for measuring the resurgence of the disease as drug resistance increases. This article illustrates the valuable contribution of localized studies to the understanding of malaria mortality trends in Africa.*

The resurgence of malaria is slowing down the health transition in Southern countries, notably in sub-Saharan Africa where it is a leading cause of death among children under five. Malaria mortality is difficult to study in this region of the world, however, due to a lack of demographic and health data, in rural areas especially. Demographic surveillance systems (DSS) provide a partial solution to this problem, but without precise medical data, death by malaria is difficult to diagnose. Since 1985, the Mlomp DSS has provided data on causes of death determined by verbal autopsies associated with parasitological test results. Situated in a region where malaria is endemic and where local healthcare facilities are good, Mlomp is ideally located for conducting medical and epidemiological studies on the resurgence of malaria and the efficacy of available treatments, and for measuring malaria mortality. After a brief review of the epidemiological context of malaria and its effects on mortality in Africa, we will estimate malaria mortality in Mlomp using not only established diagnoses, but also the information provided to make these diagnoses. We will thus seek to measure the impact of the malaria resurgence on overall mortality in this study population.

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Translated by Catriona Dutreuilh.

I. Malaria in sub-Saharan Africa

1. An age-old scourge of the Southern countries

Plasmodium falciparum malaria is a potentially lethal parasitic disease whose epidemiology varies widely between regions, depending on the climate, the environment and land use. These characteristics influence its impact on morbidity and mortality by affecting the frequency and intensity of exposure. In regions of low endemia or where malaria occurs in epidemic form, the disease can be deadly at all ages. In endemic zones, malaria mortality is high, but most victims are young children, since individuals develop premunition which reduces the risk of death as they grow older.

Known since ancient times, malaria was eradicated in Europe – including along the coastal zones of mainland France – in the 1940s by massive DDT spraying. In the early 1950s, it was still a health risk in the inter-tropical regions of the world and in most Southern countries. But the effective use of insecticides to destroy malaria-carrying mosquitoes and, above all, the wide availability of a low-cost medication, chloroquine, led to hopes that malaria would be eradicated world-wide. For example, the virtual disappearance of malaria from Sri Lanka in just two years was a spectacular success story, increasing life expectancy by an estimated twelve years.(1)

But chemical use led to the development of resistance: the mosquitoes became resistant to insecticides – which also proved toxic to humans – and the parasites to the anti-malarial drugs. In 1961, chloroquine-resistant strains of the malaria parasite emerged almost simultaneously in tropical Asia and America (Payne, 1987). But because the countries affected by malaria are poor, chloroquine remained in use as first-line treatment, and chloroquine resistance reached eastern Africa in 1978 and the west of the continent a decade later. In parallel, the malaria parasite developed resistance to the other drugs used as second- or third-line treatments, such as quinine or sulfadoxine-pyrimethamine(2) (Sibley et al., 2001; Gregson and Plowe, 2005).

The launch of the WHO Roll Back Malaria project in 1998 marked a turning point in the fight against malaria, with the development of a new strategy encompassing the many different factors at play: clinical, biological, but also sociocultural and economic. Prevention was reinforced – notably through the use of insecticide impregnated mosquito nets – and new treatments were introduced in countries still using chloroquine despite its inefficacy.(3) In therapeutic terms, the combined use of several different molecules to minimize risk of resistance is probably the most promising solution (Trape, 2001). WHO currently recommends

(1) The precise impact of malaria eradication on the mortality decline in Sri Lanka is a subject of debate, however (Molineaux, 1985 ; Langford, 1996).

(2) Fansidar®.

(3) WHO recommends withdrawing chloroquine as first-line therapy when resistance to *Plasmodium falciparum* exceeds 25% (proportion of treatment failures).

artemisinin-based combination therapy (ACT), a much more expensive form of treatment than chloroquine[4] (WHO, 2005), and less affordable for populations in developing countries (Agnamey et al., 2005; Marquet, 2003).

2. Impact of malaria on mortality in Africa

In sub-Saharan Africa, two-thirds of the population is exposed to malaria. Around 80% of malaria deaths occur in this region of the world, mainly among children under five (WHO, 2005). In 2000, the disease was responsible for an estimated 15-20% of infant and child mortality, though the exact number of malaria deaths in Africa is very difficult to determine[5] (Rowe et al., 2006; Smith et al., 2004, 2006; Snow et al., 1999a, 1999b; MARA/ARMA, 1999).

Mortality in sub-Saharan Africa has increased in recent decades. This is due mainly to AIDS, although the resurgence of malaria has also contributed to the worsening health situation (WHO, 2005). Despite certain limits,[6] surveys representative at national level, such as the Demographic and Health Surveys (DHS), provide a means to assess general mortality trends in childhood (Barbieri, 1989). They show that child mortality increased in many countries in the 1990s, including in the African countries least affected by the AIDS epidemic, such as Senegal, where malaria is the leading cause of morbidity and mortality among children under five (Ndiaye and Ayad, 2006). In the absence of national cause-of-death statistics, however, the contribution of malaria to the increase in child mortality in the 1990s is difficult to measure.

In most African countries, no civil records are kept outside the major cities: most children are not registered at birth (UNICEF, 2002), death registration is incomplete and reported ages at death are not always reliable (Lohlé-Tart and François, 1999; Hill, 1999). In addition, cause-of-death data from health infrastructures are of poor quality. In rural areas, few people are seen by a doctor before they die, and no autopsy is performed after death.[7] In 2001, only four countries of sub-Saharan Africa produced high-quality national data on causes of death[8] (Mathers et al., 2006).

(4) In the early 2000s, chloroquine-based anti-malarial treatment cost €0.11 for an adult, sulfadoxine-pyrimethamine-based treatment cost €0.18, and treatments combining artesunate with amodiaquine or sulfadoxine-pyrimethamine cost between €0.87 and €1.30 (Adjuik et al., 2004).

(5) Estimates are based on local studies to determine, by region, the population at risk of transmission and the risk of dying from malaria. The estimated number of deaths corresponds to mortality directly attributable to malaria or to mortality induced by the disease (underlying, contributing or indirect cause of death).

(6) In terms of representativeness, reliability of reporting and of retrospective information, methodological bias, etc.

(7) In Burkina Faso, for example, it is estimated that only 1 death in 12 is recorded by health institutions (Baya, 2004).

(8) Mauritius, the Seychelles, South Africa and Zimbabwe.

3. The role of demographic surveillance sites in measuring malaria mortality

Few data sources are thus available for the detailed study of mortality, especially in rural areas. Demographic surveillance systems (DSS) have been developed to provide detailed and reliable population data (Pison, 2005; Delaunay, 2002). A geographically delimited population is monitored by means of multi-round surveys following an initial census. DSSs do not provide data representative at national level, but as malaria epidemiology is strongly linked to local characteristics, they are well suited to the study of the disease.

DSS sites can provide detailed information on mortality. Whenever someone in the study population dies, the age at death is recorded, along with the probable cause of death if a verbal autopsy is carried out. A questionnaire is administered to the family of the deceased individual to record information on the reason for death: the disease, its treatment and its symptoms. A physician is then consulted to interpret the information obtained and identify a probable cause of death. This verbal autopsy method was first used in the 1950s (Biraud, 1956). It has been widely developed since then and is now used on numerous DSS sites in sub-Saharan Africa and Asia (Adjuik et al., 2006; Indepth, forthcoming).

Medical causes of death are difficult to classify, however, even in a context where they are systematically diagnosed and recorded (Meslé, 2006). Although highly informative, the method has limits which have been widely studied by researchers working on this type of data, and the scientific literature on the question has been abundant since the late 1980s (Garenne and Fontaine, 1988; Snow et al., 1992; Chandramohan et al., 1994; Anker, 1997; Fauveau, 2006; Chandramohan et al., 2005; Garenne and Fauveau, 2006; Soleman et al., 2006; Setel et al., 2006).[9]

The reliability of the method depends on various factors ranging from data collection to cause classification – choice of respondent, questionnaire used, experience of diagnosing physicians, etc. – but also on the cause of death itself. Its accuracy is generally measured in terms of sensitivity[10] and specificity[11] (Anker, 1997; Chandramohan et al., 2001). These indices serve to assess the divergence that may exist between the actual cause of death and the cause diagnosed by verbal autopsy, since this discrepancy may have a major impact on cause-specific mortality rates (Maude and Ross, 1997). Generally, deaths due to injury or diseases with very characteristic symptoms, such as scarlet fever or rabies, are accurately classified. For malaria, however, there are no pathognomonic symptoms (Rogier et al., 2005): fever, anaemia, coma, respiratory

(9) A WHO bulletin – 84(3) – issued in 2006 on mortality estimation in developing countries is partly devoted to this method.

(10) The sensitivity of the method for diagnosing cause *x* is the proportion of deaths diagnosed from cause *x* among deaths actually due to cause *x*.

(11) The specificity of the method for diagnosing cause *x* is the proportion of deaths diagnosed as not from cause *x* among deaths actually not due to cause *x*.

distress and neurological disturbances may be observed in a variety of pathologies (Marsh et al., 1996; Berkley et al., 1999). The verbal autopsy method may thus be less reliable for diagnosing malaria deaths. Local studies which have compared verbal autopsy diagnoses with clinical diagnoses show that the method is not very sensitive and moderately specific (Rowe, 2005; Anker et al., 1999; Todd et al., 1994; Snow et al., 1992). In practice, it is often impossible to measure these indices precisely because the actual cause of death is unknown.

Measurement of malaria mortality in sub-Saharan Africa thus poses a dual problem: the shortage of data on causes of death in general, and the uncertain reliability of existing data based on verbal autopsies. Although limited, current estimations of malaria mortality in Africa are nonetheless based primarily on this kind of data collected at local level (Rowe et al., 2006).

II. The Mlomp health and demographic surveillance system

1. A rural population of Senegal monitored since 1985

The Mlomp health and demographic surveillance system (HDSS) in south-western Senegal was set up in 1985 (Pison et al., 2002) to measure demographic levels and trends in a rural population of sub-Saharan Africa. In 1985, two other DSS sites – Niakhar (Garenne and Cantrelle, 1997) and Bandafassi (Pison et al., 1997), were already functioning in the centre-west and south-east of Senegal. The addition of Mlomp ensured fuller coverage of the country's demographic diversity (Map 1).

Map 1. Location of Mlomp and the two other DSS sites in rural Senegal

Since the initial census in 1985, the population of Mlomp has been surveyed annually. At each survey round, the demographic events of the preceding year – births, deaths, unions and migration – are recorded. The verbal autopsy method is used to diagnose biomedical causes of death.

2. Malaria research in Mlomp

The Mlomp region has a sub-tropical climate, with a rainy season from June to October and a dry season. *Plasmodium falciparum* malaria is mesoendemic in the area: transmission occurs throughout the year, but is especially intense over a 6-8 month period.[12] Only children are exposed to the severe and potentially fatal forms of the disease.

A range of medical research programmes have been conducted in partnership with the village dispensary since the late 1980s, notably on chloroquine resistance and the efficacy of anti-malarial treatments. Many patients who come to the dispensary with fever symptoms are given a thick blood smear test to measure the *Plasmodium falciparum* density in the blood and to diagnose a malaria attack.

The pooled findings of these programmes have revealed the impact of chloroquine resistance on mortality attributable to malaria in western Africa (Trape et al., 1998), and have confirmed the efficacy of ACT combination therapy (Adjuik et al., 2002) and its role in reducing mortality (Cissé et al., 2005). Indeed, the first two studies are very regularly cited.[13]

As the medical information recorded at the dispensary in Mlomp is used to diagnose causes of death among the population monitored by the demographic surveillance system, the reliability of diagnoses is greatly enhanced. Yet this information is neither complete nor exhaustive. Given the difficulty of determining cause of death – and more specifically death from malaria – on DSS sites, a more in-depth study of diagnosis reliability is needed to measure malaria mortality trends since 1985 and to estimate its impact on overall mortality.

3. Mlomp and its population

Mlomp is a rural community located in a woodland area surrounded by paddy fields. On 1 January 2005, the monitored population totalled 8,008 people belonging to households grouped into family concessions based on the patrilinear system. The houses have adobe walls with corrugated iron or straw roofing. The inhabitants have no electric power supply and drinking water is drawn from the area's many wells (Pison et al., 2002).

Most inhabitants of Mlomp are of the Diola (*Joola*) ethnic group, and are animists or Catholics. They speak, Diola, the local language, many speak

(12) On average, the inhabitants of Mlomp receive 25 bites from infected mosquitoes per year (Agnamey et al., 2006).

(13) According to Google Scholar, in September 2008, the article by Trape et al. had been cited 167 times and that by Adjuik et al. 145 times.

Wolof, the country's lingua franca, while French, the institutional language is taught in school. The educational infrastructure is relatively well developed and in 2000, 55% of women aged 15-49 had been to school for at least one year, compared with 20% of rural Senegalese women overall in 2005 (Pison and Enel, 2005; Ndiaye and Ayad, 2006).

Rice growing, which occupies the population during the wet season, is the main local resource. As no local cash crops are produced, the inhabitants of Mlomp migrate to earn money. The men often harvest palm wine or fish during the dry season, and the young women work in town as maids before returning to the village to marry (Pison et al., 2001). For example, on 1 January 2005, in the middle of the dry season, half of all young men and women aged 15-30 were absent from the village, and 43% of men aged 30-59.

While the total fertility rate exceeded 6 children per woman in the early 2000s in rural Senegal (Ndiaye and Ayad, 2006), women in Mlomp had 4 children on average over the period 1985-2004. This fertility level is linked to a late age at first live birth (23 years). The first birth generally occurs before marriage, when the partners are still living separately. After marriage, births are spaced by means of contraception (17% of women aged 15-49 in 2000) and breastfeeding (median duration 19 months) (Pison et al., 2001).

Over the period 1985-2004, life expectancy at birth was 60.5 years. [14] [15] Life expectancy is difficult to estimate at the national level,[16] but comparison with observed life expectancy on the other rural DSS sites in Senegal over the same period shows that mortality in Mlomp is relatively low for a rural region of Senegal. Comparison of under-five mortality produces the same conclusion (Table 1).

Table 1. Life expectancy and under-five mortality at the three rural DSS sites in Senegal, 1985-2004

	Bandafassi	Mlomp	Niakhar
Life expectancy at birth (e_0)	48 years	61 years	54 years
Under-five mortality ($_5q_0$)	239‰	101‰	202‰

Source: Pison et al. (2005).

(14) This type of demographic surveillance is limited by a "space-time window" (Delaunay, 2002): individuals are observed over a given period and in a given space, with entry into observation at the time of the initial census, by birth or immigration, and exit from observation by death or emigration. Duration models can be used to plot the population survival curve taking account of all individuals who formed part of the population at least once over the period considered.

(15) As data on mortality becomes less reliable at advanced ages, mortality observed after age 80 is ignored and a theoretical life expectancy at age 80 is applied (e_{80} = 4.7 years) which is the United Nations standard for a life expectancy at birth of 60 years (United Nations, 2002).

(16) Further to the under-five mortality estimates provided by the most recent DHS, the United Nations 2006 revision gives a life expectancy of 61.6 years for Senegal over the period 2000-2005, 6 years more than the figure given in the previous revision for the same period (United Nations, 2005 and 2007).

A retrospective survey of birth histories of women enumerated in Mlomp in 1985 revealed a sharp drop in the risk of dying before age 5 from the 1960s, in parallel with the development of health infrastructures in the area (Pison et al., 1993).

4. Health infrastructure and measures to combat malaria

As in many rural areas of sub-Saharan Africa, healthcare services in Mlomp are sparse. The nearest doctor is around 10 km from the area and the regional hospital equipped with surgical facilities is 50 km away. There is nonetheless a dispensary, opened in 1961, and a maternity clinic, opened in 1968.

These two private facilities function well and have done so for many years: working under the supervision of the district physician, a nurse is present every day at the dispensary[17] and two matrons ensure a permanent presence at the maternity clinic. In the event of complications, patients are taken by the nurse to the district hospital, or by ambulance from the district hospital to the regional hospital. All women in Mlomp give birth at the maternity clinic[18] (Enel et al., 1993). As a result, there are fewer maternal deaths on the Mlomp site than on the two other rural DSS sites in Senegal[19] (Pison et al., 2000) and neonatal mortality is relatively low. The risk of dying in the first month of life was 27‰ in 1985-2004 against 46‰ in rural Senegal as a whole over the period 1996-2005 (Ndiaye and Ayad, 2006).

For many years, monthly weighing[20] and vaccination[21] sessions have been organized. Practically all children in Mlomp receive the vaccinations recommended by the health authorities, which is rarely the case elsewhere.[22] These sessions also provide an opportunity for "get-togethers" where the matrons advise the mothers about their children's health. They focus mainly on breastfeeding, hygiene, vaccination and prevention of the main diseases not controlled by vaccination, such as intestinal infections and malaria.

(17) In the early 2000s, the nurse was seconded by a nursing assistant and a laboratory assistant. The dispensary comprises a consulting and treatment room, a laboratory, a pharmacy and an in-patient ward.

(18) Between 1985 and 2005, only 11 births (0.4% of deliveries excluding miscarriages) in the village of Mlomp took place outside the maternity clinic, including 5 on the journey from the patient's home to the clinic. In Senegal as a whole, only 44.6% of rural births in 2000-2005 occurred in a health facility (Ndiaye and Ayad, 2006).

(19) In 1985-1998, maternal mortality was 436 per 100,000 live births in Mlomp, versus 516 in Niakhar and 826 in Bandafassi (Pison et al., 2000).

(20) Since 1969, the year in which the *Programme de protection nutritionnelle et sanitaire* (Health and Nutrition Project, PPNS) was set in place.

(21) Occasional from the late 1960s, regular since 1975, they became monthly in 1982, the year in which the Expanded Vaccination Programme (EVP) was introduced in Senegal.

(22) Out of all children born in Mlomp between 1995 and 1999, still alive at age 18 months and still living in the village, 98% had been fully vaccinated before 18 months of age and 92% before 12 months (Duthé, 2006). For Senegal as a whole, the proportion in 2005 was 59% at ages 12-23 and 48% for children aged below one (Ndiaye and Ayad, 2006).

Chloroquine was used as first-line treatment against malaria in Mlomp from 1961, when the dispensary first opened. In 1975, a major programme of chloroquine-based prophylaxis was launched during the rainy season, and presumptive treatment was given to children in the form of self-medication at the first signs of fever. But with the emergence and rapid spread of choloroquine resistance from 1990, chemoprophylaxis was limited in 1993 to children under 4 and pregnant women (Trape et al., 1998; Pison et al., 1993). Chloroquine is still used for presumptive treatment of young children and quinine is used in cases of high fever and for adults. However, the chloroquine resistance of *Plasmodium falciparum* has increased steadily, and exceeded 70% in 1997 (Sokhna et al., 1997; Trape et al., 2002).

In 1999, an international study with WHO funding was set up to test an ACT combining amodiaquine+artesunate on four African DSS sites (Adjuik et al., 2002). Several hundred children aged between 6 months and 10 years were treated at the Mlomp dispensary, either with amodiaquine only,[23] or with amodiaquine+artesunate. The drugs were supplied by pharmaceutical laboratories. Encouraging results were obtained and in 2000 the entire population was treated with this ACT during the rainy season. Since 2002, treatment has been administered on a year-round basis. All these changes have been made with the agreement of the health authorities and the dispensary healthcare personnel are actively involved. Their participation is key to the success of the programme. This new first-line therapy currently costs between €0.74 for a child under five and €1.30 for an adult (Agnamey et al., 2005), plus the price of the consultation (€0.15 for an adult, and half that price for a child in 2002) and of the blood test to detect *Plasmodium falciparum* (€0.30 in 2002). Though expensive for the villagers, the treatment is highly effective and avoids the need for second-line intramuscular quinine injections which are even more costly.

In parallel, the local health organization encourages the population to use insecticide-impregnated mosquito nets, especially during the rainy season, to protect pregnant women, babies and small children in particular.

Throughout the 1990s, the health authorities had little scope for action, and a new upturn in malaria mortality was feared. The arrival of new treatments, introduced progressively since the early 2000s, has raised new hopes of progress in combating the disease.

III. Measuring malaria mortality and its impact on overall mortality since 1985

1. Protocol for determining causes of death

In Mlomp, verbal autopsies are recorded during the annual data collection round, at the earliest after the mourning period, and at the latest one year after

(23) An initial study in the late 1990s had shown amodiaquine to be more effective than chloroquine for malaria treatment in Mlomp (Brasseur et al., 1999).

death if the person died just after the previous round. Verbal autopsies are conducted by interviewers[24] from Mlomp itself, to ensure maximum comprehension in both linguistic and sociocultural terms and to guarantee a relation of trust which is vital for successful data gathering[25] (Chandramohan et al., 2005). It is the interviewers' task to find the friend or relative most capable of answering questions on the disease history and symptoms. Since 1985, the same verbal autopsy questionnaire[26] has been used for all deaths, though it includes a special section for children and women of reproductive age.[27] Once the names of the deceased and the respondent have been recorded, the latter reports what he/she believes to be the cause of death, any treatments received by the deceased during illness and the history of the deceased's illness. Questions are then asked about a whole series of symptoms,[28] and details are recorded where relevant to the deceased.

The medical information obtained from the local health institutions with the consent of the district physician enhances the reliability of verbal autopsies. The protocol for determining causes of death remained largely unchanged up to 2003. A single malaria specialist determined causes of death by visiting Mlomp at the end of the annual survey to consult the various registers[29] kept by the dispensary nurse and to check them against the verbal autopsies. Causes of death were coded in accordance with the ninth revision of the International Classification of Diseases (WHO, 1977). Only the underlying cause of death was identified and recorded.

To facilitate comparative studies, the three rural DSS sites in Senegal all adopted the same protocol in 2004. In Mlomp, this harmonization involved recruting a new interviewer with medical training and entrusting autopsy analysis to several physicians with different fields of expertise to give complementary medical opinions. Any medical information available at the dispensary is now recorded on the autopsy at the time of data collection and submitted to the diagnosing physicians in Dakar. For the study of malaria mortality, we focus on the period 1985-2003 which is homogeneous in terms of data sources, collection and archiving.

(24) Most verbal autopsies are conducted by a man, but as questions on reproduction are taboo among the Diola, it is a woman who asks questions about deaths of newborns and of women of childbearing age.

(25) Before beginning the questionnaire, the interviewer explains the reasons for the survey and asks respondents to give their verbal consent.

(26) It is the same questionnaire as the one used on the Niakhar site in 1985 and which has only been slightly modified since.

(27) This section includes questions on previous pregnancies, most recent pregnancy, delivery and state of health of the child.

(28) Fever/hot body, diarrhoea/dysentery, signs of dehydration, vomiting, convulsions and other neurological signs, breathing difficulties, coughing, rashes, wounds, burns, abscesses, bleeding, oedema, swollen belly, urinary problems, abnormal colour of urine or faeces, eye problems, pain (if death after age 2), general signs, chronic disease.

(29) Register of consultations at the dispensary, register of deaths recorded by the nurse with presumed cause, register of prenatal consultations and register of births at the maternity clinic.

2. Reliability of malaria diagnosis

Our analysis is limited to deaths occurring before age 20, since beyond that age the probability of dying from malaria is very low thanks to acquired premunition. From 1985 to 2003, no malaria deaths were diagnosed beyond age 20, and more than 80% of such deaths occurred before age 5 (Table 2).

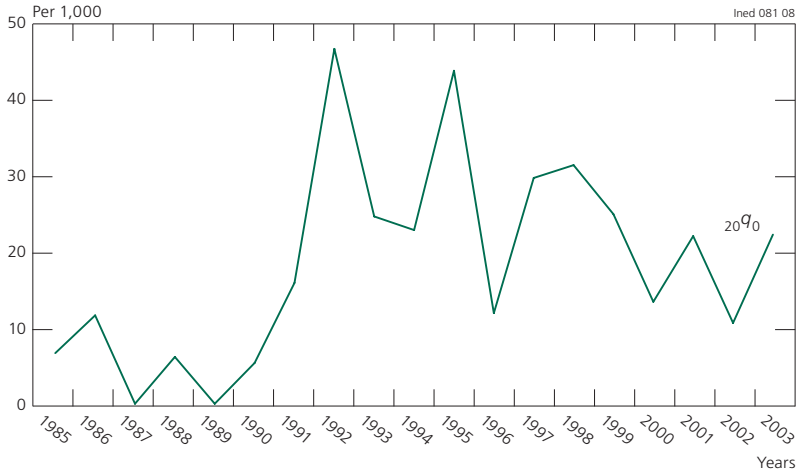
Table 2. Distribution of diagnosed malaria deaths by age group in Mlomp, 1985-2003

Age group	Number of deaths	%	aggregate %
Below age 1	8	13	13
Age 1-4	41	69	82
Age 5-9	8	13	95
Age 10-19	3	5	100
Overall	60	100	

Source: Mlomp database, 2005.

If we consider the causes of death as diagnosed, the risk of dying from malaria before age 20 has varied greatly over time, reflecting the sequence of epidemiological and therapeutic changes described above. There was practically no malaria mortality up until the early 1990s, and although it fluctuated from 1992, it rose to a mean level of over 30‰ in the middle of the decade before gradually declining (Figure 1).

Figure 1. Annual variation in risk of dying from malaria before age 20, Mlomp, 1985-2003



Source: Mlomp database, 2005.

The knowledge and experience of the physician responsible for determining cause of death may affect his/her decision to classify a death as due to malaria or otherwise (Desgrées du Loû et al., 1996). The hypothesis that the availability of medical information improves the reliability of malaria diagnosis in Mlomp endorses the validity of these data. In etiological terms, although the presence of the parasite in the blood confirms that a malaria attack occurred, it does not necessarily mean that malaria was the underlying cause of death. Moreover, thick blood smear tests were not introduced until 1989 and are not available for all children who died. Certain cases of malaria death may therefore have gone undiagnosed. In addition, not all deaths are clearly diagnosed, and those with ill-defined causes are not distributed independently across the various causes of death, whose ease of diagnosis varies (Desgrées du Loû et al., 1996; Kahn et al., 2000). Over the period 1985-2003, one-third of all recorded deaths did not have a clearly defined cause. Though the proportion is only one-quarter for deaths occurring before age 60, this is still a far from negligible share. Before age 15, half of deaths from ill-defined causes are characterized by general symptoms (fever, convulsions, chills, coma, etc.) (Table 3).

Table 3. Distribution of deaths from ill-defined causes by age group, Mlomp, 1985-2003

	Under 15	15-59	60+	Overall
Percentage of ill-defined deaths	25	24	39	32
Including general symptoms	12	4	8	8
Senility, old age	0	0	9	4
Other symptoms	4	9	9	8
Sudden death or unknown cause	9	11	14	12
Number of ill-defined deaths	105	83	286	474
Total number of deaths	426	344	727	1,497

Source: Mlomp database, 2005.

3. Definition of deaths potentially linked to malaria

To estimate the number of deaths potentially linked to malaria, we divide deaths into four groups: deaths diagnosed as malaria; deaths diagnosed as non-malarial; deaths from ill-defined causes but associated with symptoms and last, deaths from unknown causes. Within each group, we identify possible malaria deaths on the basis of available information (symptoms, medical information, age and season of death, comments of the physician making the cause-of-death diagnosis) (Table 4).

The 60 diagnosed malaria deaths from 1985 to 2003 are classified as certain (confirmed by a positive thick blood smear test), presumed (typical malaria attacks at high-risk age and in a high-risk season), or possible (contributing or concurrent cause, borderline ill-defined cause). Under this classification, almost half the diagnosed malaria deaths are certain, 43% are presumed and 12% are possible.

Table 4. Deaths potentially due to malaria occurring before age 20 by type of diagnosis, Mlomp, 1985-2003

	Degree of certainty	Number of deaths	%
Diagnosed malaria deaths			
Malaria attack and positive thick blood smear test	Certain	27	45.0
Typical malaria attack (symptoms, season, age)	Presumed	26	43.3
Malaria attack or other cause, or ill-defined death	Possible	7	11.7
	Total	60	100.0
Diagnosed non-malaria deaths			
Contributing cause or doubt	Possible	26	9.3
No doubt or negative thick blood smear test	Ruled out	253	90.7
	Total	279	100.0
Deaths from ill-defined causes with symptoms			
Indeterminate fevers or other general symptoms	Possible	45	62.5
Other symptom, no doubt or negative thick blood smear test	Ruled out	27	37.5
	Total	72	100.0
Death from unknown cause	No indication	39	100.0

Source: Mlomp database, 2005.

Deaths diagnosed as non-malarial are classified either as possible malaria deaths (doubtful diagnosis or associated malaria) or as deaths for which a malaria diagnosis is ruled out (certain diagnosis or negative blood smear test). Out of 279 deaths, more than 9% – around 30 – could be due to malaria. Most were diagnosed as deaths due to pneumonia or bronchial pneumonia, ill-defined perinatal or intestinal infections, or meningitis. Indeed, the clinical signs of certain infections are very similar to those of a malaria attack.

More than half the deaths from ill-defined causes but with associated symptoms could be linked to malaria. Of these 45 deaths, 41 correspond to description of general symptoms: 30 cases of fever, 7 of coma and 4 of convulsions.

Last, among death from ill-defined causes, we identify those for which no details are available. Deaths are classified in this category in the total absence of information from verbal autopsies or from the dispensary. These deaths cannot be linked to any specific cause and their proportional distribution across the other categories – certain, presumed, possible and ruled out – is probably the most neutral redistribution method. Over the period 1985-2003, 39 deaths before age 20 are of unknown cause.

The grouping of these deaths suggests that the share of malaria mortality in deaths before age 20 over the period 1985-2003 lies somewhere between less than 7% and almost 32%. There is a very broad range of possibles, from certain malaria deaths to those which might possibly be associated (Table 5).

In what follows, these deaths – i.e. certain, presumed or possible malaria deaths – will be qualified as deaths potentially due to malaria.

Table 5. Deaths potentially due to malaria, Mlomp, 1985-2003

Degree of certainty	Number of deaths	Number after redistribution of deaths from unknown cause	Percentage	Aggregate percentage
Certain	27	29.6	6.6	6.6
Presumed	26	28.4	6.3	12.9
Possible	78	85.4	19.0	31.9
Ruled out	280	306.6	68.1	100.0
Unknown cause	39	–	–	
Total	450	450.0	100.0	

Source: Mlomp database, 2005.

4. Impact of malaria on mortality

To study the impact of malaria on mortality, we use mortality rates based on the various predefined categories, which have the advantage of being additive. These rates are expressed in person-years.(30) Figure 2 shows the change by period of the standardized mortality rates(31) before age 20, distinguishing deaths potentially due to malaria, with deaths of unknown cause redistributed proportionally by age and period. Whatever the degree of certainty of malaria mortality, the distinction between the first period and the second is very clear, with mortality potentially due to malaria reaching 3 deaths per 1,000 people aged under 20 per year. Overall, we can thus confirm that there was an increase in malaria mortality in the early 1990s that coincides clearly with a rise in mortality levels. However, in 1995-1999, overall mortality started to fall again, while malaria mortality remained largely stable. Certain or presumed malaria mortality decreases in the last period, while possible malaria deaths remain high.

To estimate the impact of mortality potentially due to malaria, the contribution of each category to variations in life expectancy from one period to another can be calculated by age group and sex.(32) Life expectancy at birth showed large variations over the period, with a sharp decline in the early 1990s. Female life expectancy, in particular, fell dramatically by 7 years between 1985-1989 and

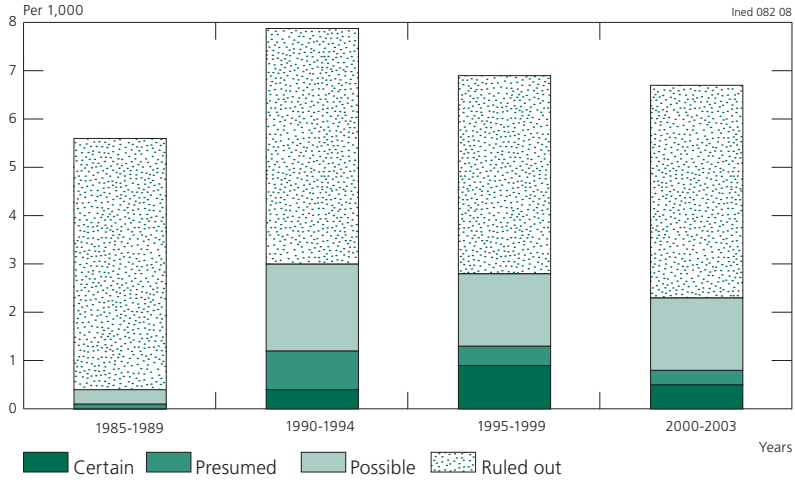
(30) The mortality rate is the ratio of deaths occurring in the population to the sum of years lived by individuals during the observation period.

(31) The use of standardized rates eliminates the age-structure effect and makes it possible to compare the levels observed over the four periods. Note that changes in the age structure of the population under 20 have very little influence on variations in mortality rates.

(32) The algorithm proposed by Andreev et al. (2002) can be used to break down the variation in life expectancy between two periods by age-specific contributions of different causes of death.

1990-1994 (Table 6). Female mortality increased at all ages between these two periods, primarily due to higher infant and child mortality. Because the survey protocol has not changed over time, and because this variation affects females only, it cannot be viewed as an artefact, although the especially low female mortality in the first period probably accentuated the effect of a worsening health situation. Malaria may also have affected girls more severely than boys.

Figure 2. Variation in standardized rate of mortality potentially due to malaria at ages 0-20 by period, Mlomp, 1985-2003 (per thousand person years)



Source: Mlomp database, 2005.

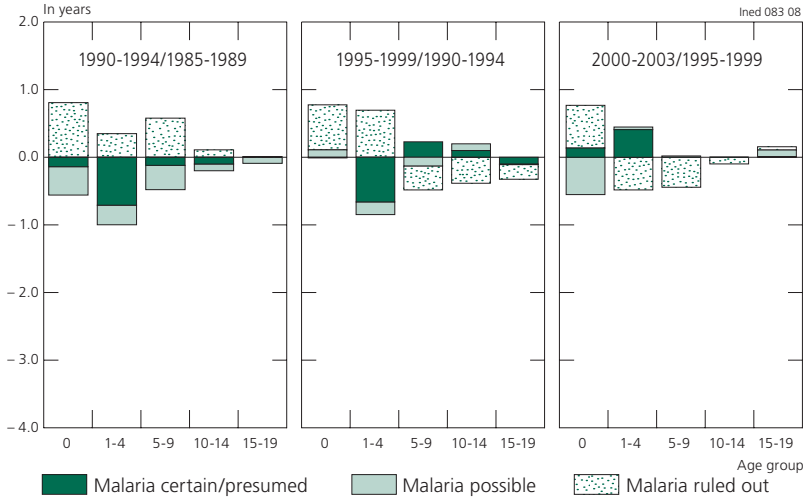
Table 6. Sex-specific trends and variations in life expectancy at birth by period, Mlomp, 1985-2003 (in years)

	1985-1989	1990-1994	1995-1999	2000-2003	Variations		
	(1)	(2)	(3)	(4)	(2)-(1)	(3)-(2)	(4)-(3)
Males	58.4	56.5	55.9	55.1	– 1.9	– 0.6	– 0.8
Females	68.5	61.5	64.5	63.8	– 7.0	+ 3.0	– 0.7
Overall	63.1	58.9	59.8	59.2	– 4.2	+ 0.9	– 0.6

Source: Mlomp database, 2005.

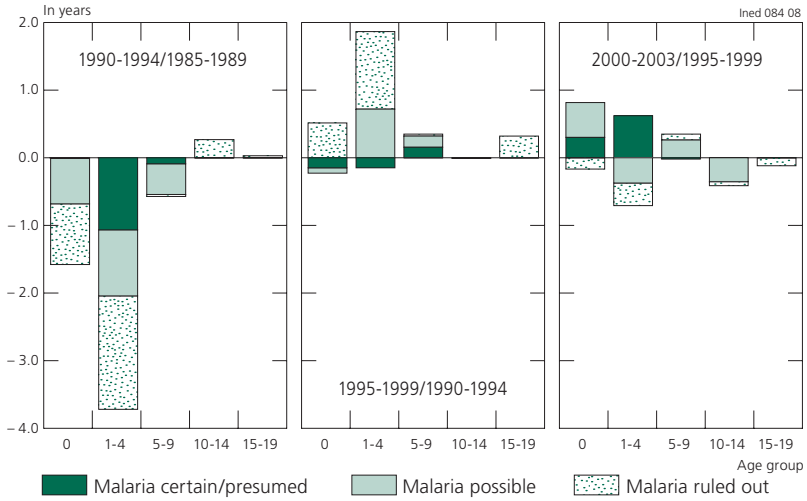
For the sake of clarity, we have grouped the first two categories of deaths potentially due to malaria (certain and presumed). For males, between 1985-1989 and 1990-1994, mortality potentially due to malaria contributed to the reduction in life expectancy in all age groups, though its effects were largely offset by lower

Figure 3. Age-specific contribution of malaria to variations in male life expectancy in Mlomp



Source: Mlomp database, 2005.

Figure 4. Age-specific contribution of malaria to variations in female life expectancy in Mlomp



Source: Mlomp database, 2005.

mortality from other non-malarial causes. Between the beginning and end of the 1990s, malaria continued to reduce life expectancy, in early childhood especially. In 2000-2003, progress was achieved in certain and presumed malaria mortality, although deaths potentially due to malaria before age 1 continued to reduce life expectancy (Figure 3). For females, the differences in life expectancy from one period to another are much larger. Malaria was responsible for an estimated 3-year decrease in life expectancy in 1990-1994 with respect to the first period, though the malaria resurgence is not the only reason for this fall. In the late 1990s, the life expectancy decrease due to non-malarial causes had been largely recouped, but not that linked to certain or presumed malaria which, for its part, was only partially recouped in 2000-2003 (Figure 4).

Overall, at ages 0-20, male and female life expectancy at birth fell by more than a year between 1985-1989 and 1990-1994 due to certain or presumed malaria. The drop is respectively 2.4 and 3.3 years if possible malaria is also included. At the end of the 1990s, males lost a further 6 months, while females recovered more than 8 months. In the early 2000s, the potential contribution of malaria changed very little for males, while females gained a year (Table 7).

Table 7. Contribution of malaria to variations in life expectancy at birth between periods by sex and at ages 0-20 in Mlomp

	Difference (years)					
	Males			Females		
	(2)-(1)	(3)-(2)	(4)-(3)	(2)-(1)	(3)-(2)	(4)-(3)
Malaria certain/presumed	– 1.1	– 0.4	+ 0.6	– 1.2	– 0.1	+ 0.9
Malaria possible	– 1.3	– 0.1	– 0.4	– 2.1	+ 0.8	+ 0.1
Malaria ruled out	+ 1.9	+ 0.4	– 0.3	– 2.3	+ 2.1	– 0.6

Periods: (1) 1985-1989; (2) 1990-1994; (3) 1995-1999; (4) 2000-2003.
Source: Mlomp database, 2005.

IV. Discussion

Malaria mortality in Mlomp is very sensitive both to changes in the epidemiological environment and to the response of health institutions. The physicians responsible for determining cause of death may be influenced by their knowledge of this context and, as a consequence, may be more or less inclined to diagnose death from malaria. The recommended procedure of asking several physicians to read the verbal autopsies and to compare their diagnoses was introduced in 2004, raising the question of its impact on the determination of causes of death. A combined analysis of Mlomp and Bandafassi data showed that the propensity to diagnose death from malaria did not appear to be modified by the fact that two physicians performed the diagnosis. The

share of deaths from ill-defined causes was substantially reduced, however, and this may have an indirect effect when these deaths are redistributed across other categories (Duthé et al., 2008). Even though this effect is probably minimal for deaths in Mlomp, thanks to the availability of medical information, future studies on malaria mortality trends will need to take account of this methodological change.[33]

The identification of deaths potentially due to malaria has enabled us to estimate the impact of malaria in broad terms. In Mlomp, deaths potentially due to malaria account for one-third of mortality among the under-20 age group, and 44% of child mortality. Studies in Kenya, Nigeria, Tanzania and Gambia[34] have shown that the reduction or eradication of malaria within a population reduces child mortality by 40-50%, a percentage which is higher than the weight of malaria alone among causes of death (Bradley, 1991; Payne et al., 1976; Molineaux, 1985; Alonso et al., 1991). In Mlomp, although the increase in certain or presumed malaria mortality was indeed accompanied by an increase in possible malaria mortality, the reduction in the former observed in the early 2000s was not associated with a corresponding decline in the latter. The substantial proportion of deaths from ill-defined or unknown causes is probably a limiting factor in our analysis.

Last, although the malaria resurgence indeed had an impact on mortality, it is not the only factor responsible for the mortality increase since the early 1990s. During the 1990 rainy season, a large circumcision-initiation ceremony was organized during which the young boys and men lived for several weeks in the bush. This caused a large number of young male deaths. A mortality peak is also observed in that year for girls, probably due to neglect, as the adults were very busy at that time (Duthé, 2006), and young female mortality remained high from 1992 to 1994. The malaria resurgence only partly explains this phenomenon, and a gender-based approach is needed to examine it more fully.

Conclusion

There is no doubt that the combination of demographic and medical surveillance in Mlomp has contributed to a better understanding of malaria epidemiology in Africa, shedding light on the development of drug resistance, the efficacy of different anti-malarial treatments, the resurgence of malaria mortality and its impact on overall mortality. But Mlomp offers the added advantage of health monitoring in parallel with demographic surveillance. Medical information can be obtained in rural areas from health huts, dispensaries

(33) The numbers of deaths in Mlomp are still too small for an analysis of this kind on this site alone.

(34) Cited by Rowe et al., 2006.

and maternity clinics, but the matching of data sources is very time-consuming, especially when the study population is large. The scarcity of complete and exhaustive medical information is regrettable.

In the fight against malaria, the diffusion of ACT treatments is a gradual process. Several initial trial stages were necessary, and ACT was then introduced only partially. The support of the population is now necessary for its use to be fully generalized. Health programmes must take account of the needs, constraints and behaviours of households and individuals, all of which influence the efficacy of the strategies deployed (Coll-Seck, 2003). Individual attitudes towards healthcare, the prescribing behaviour and information provision of healthcare personnel and the relations between carers and patients are attracting increasing attention (McCombie, 1996, 2002; Williams and Jones, 2004; Depoortere et al., 2004; Kachur et al., 2004; Souares et al., 2006). In this area, demographic and health surveillance systems provide an excellent framework for socio-anthropological studies combining both qualitative and quantitative aspects.

Acknowledgements. I would like to thank the Institut national d'études démographiques, the French Ministry of Research (programme PAL+) and the Muséum national d'histoire naturelle for their financial support; Gilles Pison, head of the DSS programme at Mlomp since 1985; all those who contributed to data collection and database updating at the INED surveys department and the team at Mlomp, Raphaël Laurent, Emmanuelle Guyavarch, Adama Sow Sambou, Jean-François Trape, Henriette Delenne (Sœur Marie-Joëlle) and Philippe Brasseur. I also wish to thank France Meslé, Myriam Khlat and the journal's anonymous reviewers for their valuable comments.

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Géraldine Duthé • **Malaria Resurgence in Senegal: Measuring Malaria Mortality in Mlomp**

Malaria is one of the leading causes of child mortality in sub-Saharan Africa. With the development of drug-resistant parasites, the fight against malaria has become complex, and because demographic and health data are scarce in the most hard-hit countries, the impact of the disease is difficult to evaluate. Demographic surveillance sites provide a means to measure levels and trends in mortality and causes of death. The data they provide are not exhaustive, however, for malaria in particular. At the Mlomp site in Senegal, information from inhabitants can be matched against data from local health facilities for more precise study of malaria mortality. From very low levels in the late 1980s, malaria mortality increased as the *Plasmodium falciparum* became resistant to chloroquine, the standard drug which, until then, had been an effective treatment. Although the introduction of new treatments in the early 2000s reduced diagnosed malaria mortality, the adoption of a broad definition of deaths attributable to malaria shows that the disease still accounts for a large share of mortality.

Géraldine Duthé • **Recrudescence du paludisme au Sénégal : la mesure de la mortalité palustre à Mlomp**

Le paludisme est l'une des principales causes de mortalité des enfants en Afrique au sud du Sahara. Or, la lutte contre cette maladie est complexe – avec le développement de résistances des parasites aux traitements administrés – et le manque de données démographiques et sanitaires dans les pays les plus touchés empêche son évaluation. Les sites de suivi démographique permettent de mesurer les niveaux et tendances de la mortalité et des causes de décès. Les données qu'ils fournissent présentent toutefois des limites, surtout dans le cas du paludisme. Au Sénégal, le site de Mlomp permet de coupler les informations collectées auprès des habitants avec celles des institutions sanitaires locales, et donc d'étudier précisément la mortalité palustre. Celle-ci, très faible à la fin des années 1980, a augmenté suite au développement d'une résistance du *Plasmodium falciparum* à la chloroquine, le traitement couramment utilisé et jusque-là efficace. L'introduction de nouveaux traitements au début des années 2000 a bien permis de réduire la mortalité palustre diagnostiquée mais l'adoption d'une définition large des décès attribuables au paludisme montre qu'elle représenterait encore une part importante de la mortalité.

Géraldine Duthé • **Recrudecimiento del paludismo en Senegal : la medida de la mortalidad palúdica en Mlomp**

El paludismo es una de las principales causas de mortalidad de los niños en África al sur del Sahara. Ahora bien, la lucha contra esta enfermedad es compleja – con el desarrollo de resistencias de los parásitos a los tratamientos administrados – y la falta de datos demográficos y sanitarios en los países más afectados impide su evaluación. Los centros de seguimiento demográfico permiten medir los niveles y tendencias de la mortalidad y de las causas de muertes. Los datos que proporcionan presentan sin embargo límites, sobre todo en el caso del paludismo. En Senegal, el centro de Mlomp permite aparejar las informaciones recogidas ante los habitantes con las de las instituciones sanitarias locales y por lo tanto estudiar con precisión la mortalidad palúdica. Esta, muy reducida al final de los años 1980, ha aumentado a raíz del desarrollo de una resistencia del *Plasmodium falciparum* a la cloroquina, el tratamiento corrientemente utilizado y hasta la fecha eficaz. La introducción de nuevos tratamientos a principios de los años 2000 ha permitido efectivamente reducir la mortalidad palúdica diagnosticada pero la adopción de una definición amplia de las muertes debido al paludismo muestra que representaría todavía una proporción importante de la mortalidad.

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