ELIMINATING MALARIA

Case-study 7

Elimination of malaria on the island of Reunion: 40 years on

UCSF GLOBAL HEALTH SCIENCES
THE GLOBAL HEALTH GROUP
From evidence to action

ensemble contre les moustiques

World Health Organization

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The authors remain responsible for any errors and omissions.

ACRONYMS AND ABBREVIATIONS

ABER	annual blood examination rate
ACT	artemisinin-based combination therapy
ARS-OI	French Regional Health Agency – Indian Ocean
CIRE	Regional Unit of the Institute for Public Health Surveillance
CVAGS	health surveillance, alert and administration unit
DDASS	Departmental Office for Health and Social Action
DDT	dichlorodiphenyltrichloroethane
DRASS	Regional Office for Health and Social Action
GMEP	Global Malaria Eradication Programme
GMP	Global Malaria Programme
IRS	indoor residual spraying
InVS	Institute for Public Health Surveillance
SPILF	French-Speaking Society for Infectious Diseases
WHO	World Health Organization

GLOSSARY

The terms listed in this glossary are defined according to their use in this publication. They may have different meanings in other contexts.

active case detection

The detection of malaria infections at community and household level, in population groups that are considered to be at high risk. Active case detection can be conducted as fever screening followed by parasitological examination of all febrile patients or as parasitological examination of the target population without prior fever screening.

annual blood examination rate

The number of examinations of blood slides for malaria by microscopy per 100 population per year.

attack phase

In malaria eradication terminology, the phase during which antimalarial measures applicable on a large scale and aiming at the interruption of transmission are applied on a total coverage basis in an operational area. The attack phase is sometimes called the period of total-coverage spraying.[1]

case-based surveillance

Every case is reported and investigated immediately (and also included in the weekly reporting system).

case definition (control programmes)

confirmed malaria – Suspected malaria case in which malaria parasites have been demonstrated in a patient's blood by microscopy or a rapid diagnostic test.

presumed malaria – Suspected malaria case with no diagnostic test to confirm malaria but nevertheless treated presumptively as malaria.

suspected malaria – Patient illness suspected by a health worker to be due to malaria. Fever is usually one of the criteria.

[1] Terminology of malaria and malaria eradication. Geneva: World Health Organization; 1963.

case definition (elimination programmes)

autochthonous – A case locally acquired by mosquito-borne transmission, i.e. an indigenous or introduced case (also called "locally transmitted").

imported – A case whose origin can be traced to a known malarious area outside the country in which it was diagnosed.

indigenous – *Any case* contracted locally (i.e. within national boundaries), without strong evidence of a direct link to an imported case. Indigenous cases include delayed first attacks of *Plasmodium vivax* malaria due to locally acquired parasites with a long incubation period.

induced – A case whose origin can be traced to a blood transfusion or other form of parenteral inoculation but not to normal transmission by a mosquito.

introduced – A case contracted locally, with strong epidemiological evidence linking it directly to a known imported case (first generation from an imported case, i.e. the mosquito was infected from a case classified as imported).

locally transmitted – A case locally acquired by mosquito-borne transmission, i.e. an indigenous or introduced case (also called "autochthonous").

malaria – *Any case* in which, regardless of the presence or absence of clinical symptoms, malaria parasites have been confirmed by quality-controlled laboratory diagnosis.

case investigation

Collection of information to allow classification of a malaria case by origin of infection, i.e. imported, introduced, indigenous or induced. Case investigation includes administration of a standardized questionnaire to a person in whom a malaria infection is diagnosed.

case management

Diagnosis, treatment, clinical care and follow-up of malaria cases.

case notification

Compulsory reporting of detected cases of malaria by all medical units and medical practitioners, to either the health department or the malaria elimination service (as laid down by law or regulation).

certification of malaria-free status

Certification granted by WHO after verification that the chain of local human malaria transmission by *Anopheles* mosquitoes has been fully interrupted in an entire country for at least 3 consecutive years.

consolidation phase

In malaria eradication terminology, the phase that follows the attack phase; it is characterized by active, intense and complete surveillance with the object of eliminating any remaining infections and proving the eradication of malaria. It ends when the criteria for eradication have been met.[1]

elimination

Reduction to zero of the incidence of infection by human malaria parasites in a defined geographical area and as a result of deliberate efforts. Continued measures to prevent re-establishment of transmission are required.

[1] Terminology of malaria and malaria eradication. Geneva: World Health Organization; 1963.

endemic

Applied to malaria when there is an ongoing, measurable incidence of cases and mosquito-borne transmission in an area over a succession of years.

epidemic

Occurrence of cases in excess of the number expected in a given place and time.

eradication

Permanent reduction to zero of the worldwide incidence of infection caused by human malaria parasites as a result of deliberate efforts. Intervention measures are no longer needed once eradication has been achieved.

evaluation

Attempts to determine as systematically and objectively as possible the relevance, effectiveness and impact of activities in relation to their objectives.

focus

A defined, circumscribed locality situated in a currently or formerly malarious area and containing the continuous or intermittent epidemiological factors necessary for malaria transmission: a human community, at least one source of infection, a vector population and the appropriate environmental conditions. Foci can be classified as endemic, residual active, residual non-active, cleared up, new potential, new active or pseudo.

gametocyte

The sexual reproductive stage of the malaria parasite present in the host's red blood cells.

hypnozoite

The dormant stage of the malaria parasite present in the host's liver cells (limited to infection with *Plasmodium vivax* and *P. ovale*).

incubation period

The time between infection (by inoculation or otherwise) and the first appearance of clinical signs.

intervention (public health)

Activity undertaken to prevent or reduce the occurrence of a health condition in a population. Examples of interventions for malaria control include the distribution of insecticide-treated mosquito nets, indoor residual spraying with insecticides, and the provision of effective antimalarial therapy for prevention or curative treatment of clinical malaria.

local mosquito-borne malaria transmission

Occurrence of human malaria cases acquired in a given area through the bite of infected *Anopheles* mosquitoes.

malaria-free

An area in which there is no local mosquito-borne malaria transmission and the risk for acquiring malaria is limited to introduced cases only.

malaria incidence

The number of newly diagnosed malaria cases during a specified time in a specified population.

malaria prevalence

The number of malaria cases at any given time in a specified population, measured as positive laboratory test results.

monitoring (of programmes)

Periodic review of the implementation of an activity, seeking to ensure that inputs, deliveries, work schedules, targeted outputs and other required actions are proceeding according to plan.

national focus register

Centralized database of all malaria foci in a country.

national malaria case register

Centralized database of all malaria cases registered in a country, irrespective of where and how they were diagnosed and treated.

outpatient register

List of patients seen in consultation in a health facility; the register may include the date of consultation; patient's age, place of residence and presenting health complaint; tests performed; and diagnosis.

parasite prevalence

Proportion of the population in whom *Plasmodium* infection is detected at a particular time by means of a diagnostic test (usually microscopy or a rapid diagnostic test).

passive case detection

Detection of malaria cases among patients who, on their own initiative, go to a health post for treatment, usually for febrile disease.

population at risk

Population living in a geographical area in which locally acquired malaria cases occurred in the current year and/or previous years.

rapid diagnostic test

An antigen-based stick, cassette or card test for malaria in which a coloured line indicates that plasmodial antigens have been detected.

rapid diagnostic test positivity rate

Proportion of positive results among all the rapid diagnostic tests performed.

receptivity

Relative abundance of anopheline vectors and existence of other ecological and climatic factors favouring malaria transmission.

re-establishment of transmission

Renewed presence of a constant measurable incidence of cases and mosquito-borne transmission in an area over a succession of years. An indication of the possible re-establishment of transmission would be the occurrence of three or more introduced and/or indigenous malaria infections in the same geographical focus, for two consecutive years for *P. falciparum* and for three consecutive years for *P. vivax*.

relapse (clinical)

Renewed manifestation of an infection after temporary latency, arising from activation of hypnozoites (and therefore limited to infections with *P. vivax* and *P. ovale*).

relapsing case

A case contracted locally some time ago (maximum admissible period is equal to the natural life-span of *P. vivax* or *P. ovale* in the human host) or a recrudescence of *P. falciparum* or *P. malariae* after a period of unrecognized latency.[1]

sensitivity (of a test)

Proportion of people with malaria infection (true positives) who have a positive test result.

slide positivity rate

Proportion of microscopy slides found to be positive for *Plasmodium* among the slides examined.

specificity (of a test)

Proportion of people without malaria infection (true negatives) who have a negative test result.

surveillance (control programmes)

Ongoing, systematic collection, analysis and interpretation of disease-specific data for use in planning, implementing and evaluating public health practice.

surveillance (elimination programmes)

That part of the programme designed for identification, investigation and elimination of continuing transmission, prevention and cure of infections, and final substantiation of malaria elimination.

transmission intensity

Rate at which people in a given area are inoculated with malaria parasites by mosquitoes. This is often expressed as the "annual entomological inoculation rate", which is the number of inoculations with malaria parasites received by one person in one year.

transmission season

Period of the year during which mosquito-borne transmission of malaria infection usually takes place.

vector control

Measures of any kind against malaria-transmitting mosquitoes intended to limit their ability to transmit the disease.

vector efficiency

Ability of a mosquito species, in comparison with another species in a similar climatic environment, to transmit malaria in nature.

[1] Guidelines on the elimination of residual foci of malaria transmission. Cairo: WHO Regional Office for the Eastern Mediterranean; 2007 (EMRO Technical Publications Series, No. 33).

vectorial capacity

Number of new infections that the population of a given vector would induce per case per day at a given place and time, assuming conditions of non-immunity. Factors affecting vectorial capacity include: the density of female anophelines relative to humans; their longevity, frequency of feeding and propensity to bite humans; and the length of the extrinsic cycle of the parasite.

vigilance

A function of the public health service during a programme for prevention of reintroduction of transmission, consisting of watchfulness for any occurrence of malaria in an area in which it had not existed, or from which it had been eliminated, and application of the necessary measures against it.

vulnerability

Either proximity to a malarious area or the frequency of influx of infected individuals or groups and/or infective anophelines.

SUMMARY

This document first explains how the island of Reunion eliminated the transmission of malaria and the efforts that were required to confirm this elimination. It goes on to describe the combined actions that have enabled this malaria-free status to be maintained for more than 40 years.

History of malaria and malaria control

The island of Reunion is a department of France situated in the Indian Ocean, 700 km east of Madagascar. At altitudes below 500 m, its climate is highly conducive to the development of *Anopheles arabiensis*, the sole vector present. In the past, mesoendemic malaria (predominantly *Plasmodium falciparum*) was transmitted around the entire coastline, causing high mortality until the late 1940s.

The elimination of malaria, 1949–1967

From 1949, all dwellings at altitudes below 500 m were sprayed yearly for four years with dichlorodiphenyltrichloroethane (DDT), and the chemical was also spread over breeding places on the outskirts of towns every two weeks. The results were spectacular, with parasite indexes reduced to less than 0.2% and mortality reduced by 90% in just four years (from 1357 deaths in 1949 to 138 in 1952). Larval control was subsequently strengthened – but at the expense of indoor spraying programmes, which tapered off and were essentially discontinued in 1961.

The consolidation phase began in 1966, starting with active case detection of more than 10 000 cases of fever a year in known foci, in home settings. This approach remained in use for five years until the introduction of mandatory case reporting by health care facilities (an obligation that still applies today). Routine case detection among the contacts of infected cases, screening of blood donations and a central case register were also established at this time. The last autochthonous cases were reported in 1967, and in 1979 the World Health Organization (WHO) certified that the disease had been eliminated.

Prevention of reintroduction

No case of autochthonous transmission has been detected for more than 40 years, although there have been 23 locally acquired cases (4 transfusion cases and 19 introduced) (see Figure 1). Prevention of reintroduction is based on passive case detection and the early treatment of imported cases, combined with a larval control programme guided by rigorous entomological surveillance.

Since 1971, travellers from endemic areas have been registered upon arrival and monitored by telephone contact for the next two weeks; until 2004 they were also subject to active case detection measures. Of the 4205 imported cases recorded between 1967 and 2010, 87% had been infected in Comoros or Madagascar. The number of travellers arriving from malaria-infected areas has steadily increased, exceeding 150 000 in 2010. However, the number of imported cases has declined significantly since 2000: in 2010, the imported case rate was no more than 56/100 000 travellers at risk.

Significant resources are mobilized for larval control measures, with treatments routinely performed every two weeks on more than 500 referenced larval breeding sites. By contrast, indoor spraying has been rare since the campaigns of 1961.

The vector, which rapidly became exophilic following the spraying campaigns, has since disappeared from some areas; it appears to survive in just three non-contiguous coastal districts. Its vectorial capacity is

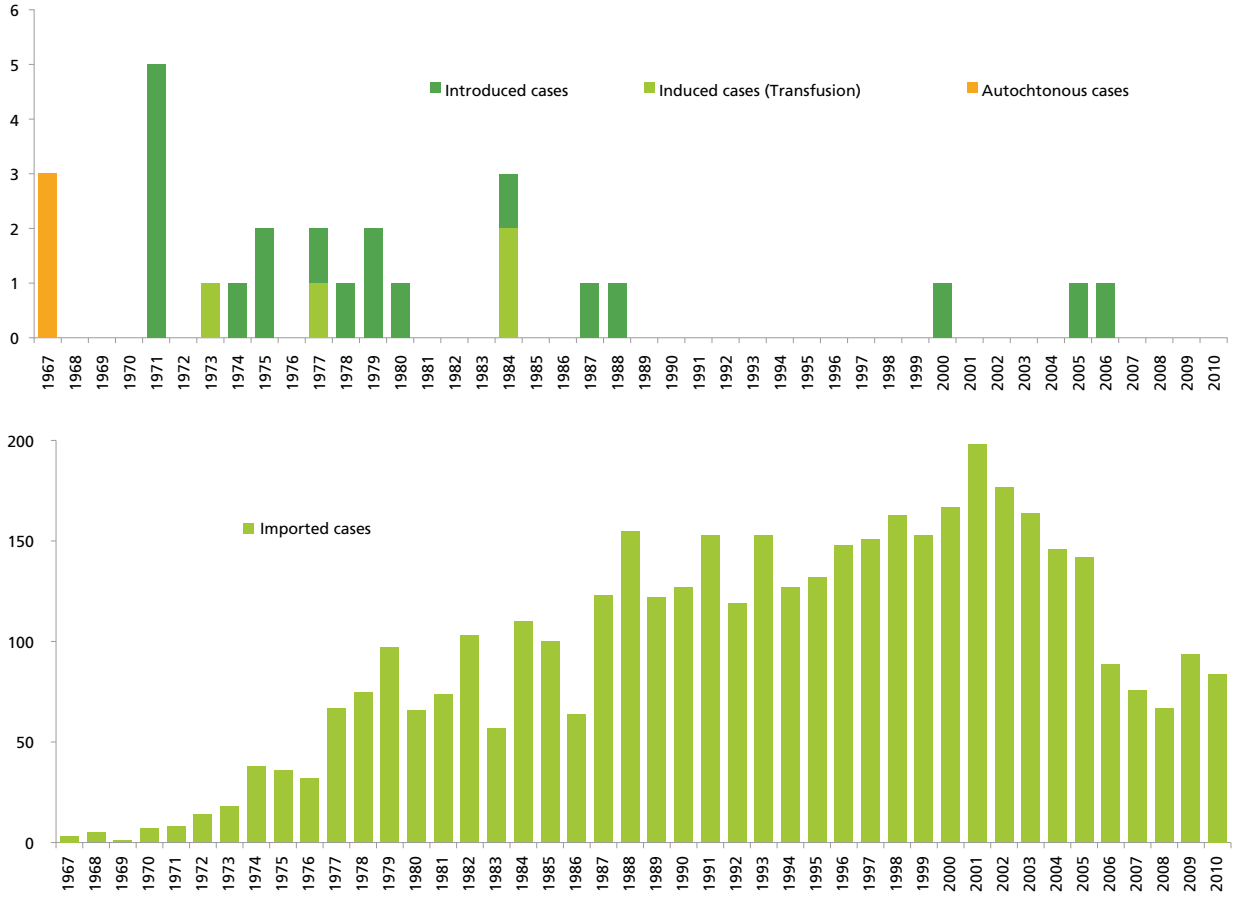
thought to have been reduced still further by the advent of modern housing, and its lifespan exceeds the threshold necessary for the development of *P. falciparum* only in certain areas during the hot and rainy season.

Outlook

The case of Reunion is unique: it is the only African territory to become malaria-free under the Global Malaria Eradication Programme (GMEP) that has been able to maintain this status to date, despite a tropical biotope highly conducive to transmission of the disease.

The transmission of malaria was interrupted in less than 20 years, but a further decade of rigorous consolidation was required to guarantee effective elimination of the disease. Significant resources were subsequently required for more than 30 years to prevent the reintroduction of malaria, given the persistence of the vector and the considerable influx of parasites from neighbouring countries. Current initiatives to reduce receptivity using larvicides, to reduce vulnerability through passive detection and to monitor travellers arriving from endemic areas are likely to continue in order to prevent the future reintroduction of malaria to Reunion.

Figure 1. Distribution of autochthonous, transfusion, introduced and imported cases – Reunion, 1967–2010[a]



[a] *Based on data from references 1–9.*

INTRODUCTION

Series of malaria elimination case-studies

If countries are to make well-informed decisions on whether or how to pursue malaria elimination, an understanding of historical and current experiences of malaria elimination and prevention of reintroduction in other countries – particularly those in similar eco-epidemiological settings – is critical. The Global Malaria Programme of the World Health Organization (WHO/GMP) and the Global Health Group of the University of California, San Francisco – in collaboration with national malaria programmes and other partners and stakeholders – are jointly conducting a series of case-studies on elimination of malaria and prevention of reintroduction. The objective of this work is to build an evidence base to support intensification of malaria elimination as an important step in achieving international malaria targets.

Ten case-studies are being prepared that, together, will provide insights into and lessons to be learnt from a wide range of elimination approaches, geographical settings and progress towards the goal of zero local transmission.

The island of Reunion was chosen as a unique example of a territory infested by the African vector *Anopheles arabiensis*, where elimination was achieved during the Global Malaria Eradication Programme (GMEP) and has been maintained to date.

Data collection and analysis methods for the case-study are elaborated in Annex 1.

Malaria elimination initiatives in Africa

Interregional collaboration can be a key factor in achieving elimination. In 1997, five countries of North Africa (Algeria, Egypt, Libya, Morocco and Tunisia) launched an interregional elimination programme *(10)*, which is now almost complete. Since the certification of malaria elimination in Morocco *(11)*, transmission north of the Sahara has persisted only in southern Algeria *(12)*. As yet, there has been no similar collaborative initiative to eliminate malaria from the southern borders of the Sahara.

In 2007, the African Union made elimination a long-term goal for the continent *(13)*, and ministers of health from the Southern African Development Community approved a new strategy that set progressive elimination targets for six Member States to reach by 2015 *(14)*. The regional initiative "Elimination 8" was launched in 2009 in eight neighbouring countries to combine skills and efforts in eliminating malaria in Botswana, Namibia, South Africa and Swaziland by 2015. (The initiative also includes Angola, Mozambique, Zambia and Zimbabwe.)

In 2010, Cape Verde entered the pre-elimination phase, and a number of island territories in the African tropical zone (Bioko Island in Equatorial Guinea, Sao Tome and Principe, and Zanzibar) are currently considering committing on a medium-term basis. It therefore seems an opportune moment to reflect on past experiences that have enabled transmission to be interrupted permanently in areas where receptivity was high. It is equally important to plan ahead by collecting available information and lessons on the prevention of reintroduction phases, which are quite poorly documented.

Malaria on the island of Reunion

The island of Reunion and its neighbour Mauritius were the only African territories in which malaria was eliminated during the GMEP. Vector control began in 1949 and transmission was successfully interrupted in 1967. WHO granted certification of elimination in 1979, following the implementation of active case detection and strengthening of surveillance. Nevertheless, since the vector is still present today – and the island is constantly exposed to parasites imported from other countries – considerable efforts are devoted to avoiding the reintroduction of malaria.

This document first explains how the island of Reunion eliminated the transmission of malaria and the efforts that were required to confirm this elimination. It goes on to describe the combined actions that have enabled this malaria-free status to be maintained for more than 40 years.

COUNTRY PROFILE

Geography, population and economy

The island of Reunion is an overseas department of France, located in the south-west Indian Ocean at 21° south and 55° east. It is 700 km east of Madagascar and 170 km south-west of the island of Mauritius. Covering an area of 2512 km2, Reunion has a rugged relief shaped by extensive erosion. The highest point stands at 3071 metres, and the island is the location of one of the world's most active volcanoes. Although the island has only nine permanent waterways, there are hundreds of narrow ravines which dry up on a regular basis.

The climate has two seasons: the southern winter from May to October, which is cool and dry, and the southern summer from November to April, when temperatures and humidity are high and precipitation is abundant, especially during cyclones and tropical depressions. The island's rainfall is its most remarkable meteorological phenomenon: Reunion holds all the world rainfall records for periods of between 12 hours and 15 days.

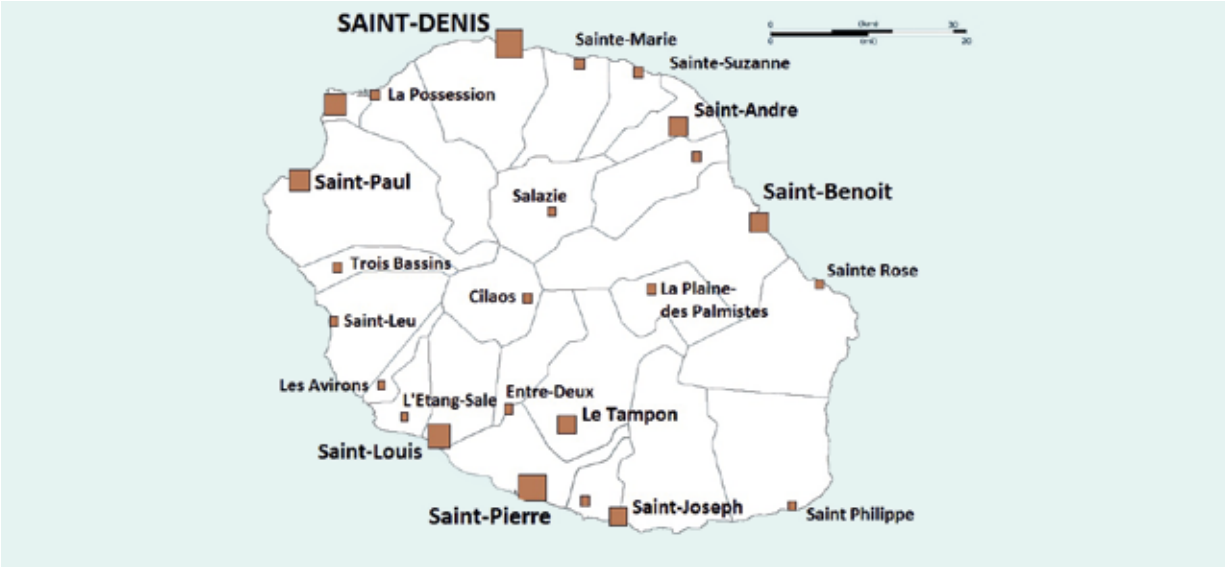
There are three climatic zones with widely different precipitation levels. The "windward" region, to the east, has a tropical maritime climate. It is frequently subject to trade winds and temperatures are moderate throughout the year (24 °C on average); precipitation is high (2.5–4 m per year on average) and the vegetation is lush. The "leeward" region, to the west, has a dry tropical climate characterized by temperatures 1–2 °C higher and far lower levels of precipitation (0.5–1.5 m per year on average). In regions above 500 m in altitude – about two-thirds of the island's area – the climate features a wider range of temperatures (16–23 °C) and higher rainfall than on the coasts.

The island has been inhabited only since the middle of the 17th century. In 1715, coffee plants from Yemen were introduced, which created a great need for a labour force. Many slaves were therefore brought from Madagascar, East Africa and India, a trend that was further encouraged by the development of sugarcane plantations from 1750 onwards. Waves of workers from China and India and from neighbouring islands (Comoros and Madagascar) arrived throughout the 19th century. Reunion is now home to a largely mixed-race society with a rich mosaic of cultures.

Reunion has been a French overseas department since 1946; its inhabitants have full French nationality and the island has the same legal and administrative status as the departments of metropolitan France. It is administered by a General Council composed of 49 elected representatives, one from each canton. It is divided into four arrondissements, 49 cantons and 24 communes (see Annex 2). Since 1982, the island of Reunion has also been an overseas region of France, administered by a Regional Council responsible for promoting economic, social, health-related, cultural and scientific development and for land management. On account of its status as a French overseas region, Reunion also receives funding from the European Union.

The island of Reunion is currently the most populated of the French overseas departments. In the 2008 census, the population was 808 250, with an average density of 323 inhabitants per km2. Most of the population is concentrated on the coasts where density can reach 1000 inhabitants per km2. The urban fabric is relatively well-developed, with seven towns of more than 30 000 inhabitants (see Figure 2) in addition to the administrative centre, Saint-Denis. The highlands of the island's interior are sparsely populated, however, owing to the steepness of the terrain and the lack of cultivable land.

Figure 2. Map of urban centres and communes of Reunion



Source : JO Guintran

The population of Reunion is young, with 35% of its inhabitants under the age of 20 years (compared with 25% in metropolitan France) and only 12% aged 60 or over (21% in metropolitan France). The birth rate was 18.8 per 2000 inhabitants in 2006, compared with 12.7 in metropolitan France, and the fertility rate remains high at around 2.5 children per woman since 2000. Compared with metropolitan France, the age pyramid has a wider base. Conversely, the segment between 20 and 40 years is narrower as a result of young adults leaving the island to study or work in metropolitan France *(15)*.

Incomes are considerably lower in Reunion than in metropolitan France: gross domestic product was €17 520 per inhabitant in 2009 compared with €29 574 per inhabitant for the whole of France *(16)*. The sugar industry still plays an important role in the island's economy: sugarcane is grown on 57% of the 44 500 hectares of cultivable land and – directly and indirectly – the industry provides more than 12 000 jobs. Other industry is less important and economic activity is primarily centred on the tertiary sector, e.g. administration, retail and services. Unemployment on the island stands at 28.9%, compared with 9.3% in France as a whole, and more than 55% of those aged under 25 years are unemployed *(16)*.

Health system and health of the population

The structure of health services is similar to that in all other French departments. At one time, all activities relating to prevention and care were coordinated by the Departmental Office for Health and Social Action (DDASS), the Regional Office for Health and Social Action (DRASS) and the regional hospitalization agency. In 2010, these bodies were merged as part of a health system reform, which led to the creation of the French Regional Health Agency – Indian Ocean (ARS-OI). This agency currently oversees the Regional Health Plan 2012–2016, which comprises 14 health priorities.

Reunion has modern health care facilities, spread more or less evenly over the island. Physicians, however, are based primarily in urban areas, and rural communes located far inland are less well covered.

Almost 53% of the population receives free health care thanks to the system of universal health coverage. More than 5.8 million consultations and visits were conducted by private general practitioners in Reunion in 2010, or an average of seven per inhabitant per year. There are 1980 hospital beds, spread over three public hospitals and six private clinics. The density of health professionals is lower than in metropolitan France: in 2009 there were 269 doctors and 609 nurses per 100 000 inhabitants, compared with 332 and 789 respectively for metropolitan France. Infant mortality was 7.9 per 1000 in 2005, compared with 3.5 per 1000 in metropolitan France *(16)*.

In recent years, Reunion has experienced extremely rapid demographic change. Between 1990 and 2006, life expectancy at birth rose by 4.4 years for men and 2.7 years for women. In 2008 it stood at 74.6 years for men and 82.1 years for women *(16)*. The gap between men and women – and the difference between Reunion and metropolitan France – is narrowing.

Reunion has also undergone a marked epidemiological transition over the past five decades and is today relatively well protected against the majority of infectious diseases. Chronic illnesses and cancers, however, have become significant public health problems. Between 2006 and 2008, more than 28% of deaths in Reunion were linked to cardiovascular illnesses and 23% were due to cancer. Death rates in every age group and for all causes are higher overall than those in the rest of France, and are particularly high for asthma and diabetes *(15)*.

With 667 patients screened and treated in 2009, HIV/AIDS infection is a relatively minor cause of morbidity and mortality in Reunion, unlike in the French departments in the Americas. Following a dramatic decline that started in 1996, the tuberculosis prevalence rate has been stable since 2003; the annual incidence in 2005 was 6.7 new cases reported per 100 000 inhabitants.

The vectors *Aedes aegypti* and *Ae. albopictus* are present on the island *(17)*, which means that the introduction of arboviruses is a danger. In 1978, the island saw an epidemic of type 2 dengue fever, during which the clinical attack rate was estimated at 30–35% *(18)*. In 2004, 228 cases of type 1 dengue fever were recorded *(19)*. However, the greatest impact was undoubtedly caused by the chikungunya epidemic of 2006, which affected 38% of the population and was responsible for serious economic damage.

HISTORY OF MALARIA AND MALARIA CONTROL

Parasites and vectors

Investigations conducted in the 1950s revealed a predominance of *Plasmodium falciparum* over *P. vivax*, with a low percentage of *P. malariae*. The proportion of *P. falciparum* then declined every year after spraying campaigns began. Since elimination, *P. falciparum* has been predominant among imported cases (see Annex 3). Today, *Anopheles arabiensis* is considered to be the only species of malaria vector on the island of Reunion, although it is possible that *An. funestus* and *An. merus* were present before the first DDT spraying campaigns *(20)*.

Initial introduction in 1868

Reunion has been inhabited only since 1662. It seems that there were originally no vector mosquitoes on the island, which was known for its healthy conditions, in comparison with Comoros and Madagascar, which were both severely affected by malaria.

It is possible that *An. arabiensis* was introduced through increased maritime traffic starting in 1850, as well as by the opening of a steam navigation line that significantly shortened travel time between Reunion and Madagascar *(21)*. Establishment of the vector was aided by deforestation resulting from the expansion of sugarcane monoculture at the start of the 19th century *(22)*.

The introduction of malaria to the island of Reunion was relatively sudden, occurring in 1868, three years after transmission began on Mauritius. One hypothesis attributes this to the arrival of 450 Indian immigrants, hired as labourers for the sugar industry and brought over from Calcutta on an English ship *(23)*. A second theory suggests that infected mosquitoes arrived from neighbouring Mauritius, 170 km away, carried by the high winds associated with a cyclone *(24)*. The outbreak of an unknown fever – subsequently identified as malaria when treatment with quinine proved effective *(25)* – caused several deaths among Indian immigrants and colonists. (It must be remembered that the parasite was not identified, by Laveran, until 1884– and that its cycle of transmission was explained by Ross only in 1899.)

Beginning in Saint-Denis, malaria spread around the entire Reunion coastline between 1869 and 1879 *(26)*. From Saint-Louis, the disease spread progressively through the villages along the Cirque de Cilaos caldera, reaching an altitude of 1200 metres in 1901 *(27)*.

First control measures (1900–1948)

By the end of the 19th century, malaria was acknowledged as the cause of one-third of annual deaths, and malaria mortality had a significant impact on demographic trends *(22)*.

The first malaria control measures (wetland drainage, gutter cleaning, breeding site destruction, petroleum spreading) were put in place at the start of the 20th century but were implemented only on a small scale. Their effectiveness was therefore limited and the disease remained highly endemic.

In 1914, a disease prevention and disinfection service was created and systematic chemoprophylaxis with quinine was introduced in schools. Officials from the service were responsible for distributing quinine and leading teams to destroy mosquito breeding sites. Quinine was extracted locally by the health services from the bark of cinchona trees planted for the purpose by the forestry service.

In the wake of the Second World War, the island of Reunion was completely devastated. Many of its 242 000 inhabitants suffered from extreme poverty and malnutrition and the infant mortality rate was

145 per 1000. In 1946, 32% of the 54 580 medical consultations concerned malaria (17 459 cases), and in 1948 the infection was considered responsible for 26% of the deaths that occurred (1779 out of 6898). A malaria survey conducted in 1949 on 2300 children from 12 coastal communes revealed an average spleen rate of 28.9%; in Saint-Denis and Le Port the rate was around 45%. Parasite prevalence rates were much lower (average 2.9%) due to the chemoprophylaxis *(28)*.

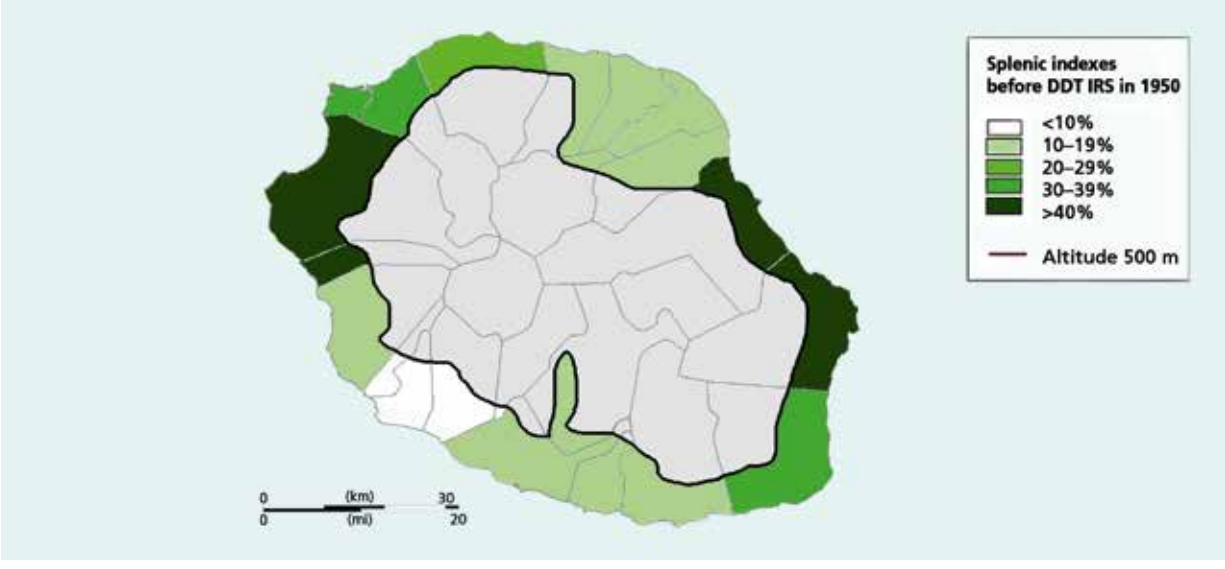
In 1946, French Guiana, Guadeloupe, Martinique and Reunion became overseas departments of France, with consequent strengthening of the administrative sector to bring it into line with metropolitan standards. Reunion received a considerable influx of public funds for its social, education and health services. During this period of enthusiasm and post-war reconstruction, France and the countries of southern Europe made a commitment to eliminate malaria.

Elimination during the Global Malaria Eradication Programme

The availability of DDT enabled more effective vector control actions to be planned in Reunion, as in other areas of the world. Intensive malaria control campaigns were organized in many malaria-infected areas. Reunion's malaria control programme was devised in 1949 and the first malaria surveys were carried out. A survey of nearly 9000 children conducted in 1950 enabled identification of the most infected communes on the island on the basis of spleen rates. Transmission had spread around the island's coastline and exhibited hypo- to meso-endemicity, with several hyperendemic foci on the "windward" coast between Sainte-Anne and Sainte-Rose (see Figure 3).

The attack phase began in 1950 and lasted four years. It was based on a yearly cycle of indoor DDT spraying around the entire coastline at altitudes below 500 metres, and DDT spreading in breeding places on the outskirts of towns every two weeks.

Figure 3. Map showing endemicity on the coast of Reunion before the 1950 spraying campaigns – spleen rates by commune[a]



[a] *Map based on data from reference 20.*

Indoor residual spraying (IRS) was carried out in 30 000 homes and thus covered half of the population, i.e. 130 000 people. Breeding sites were treated throughout the dry season. The cities of Saint-Denis, Saint-Pierre and Saint-Paul were treated initially, with cork powder containing 5% DDT. In subsequent dry seasons, larval control was implemented in virtually all coastal areas across a strip averaging 2 km in width, this time using petroleum containing 5% DDT. If there was heavy rain, treatment was carried out weekly rather than every two weeks.

The results were swift and spectacular. Surveys carried out each year on around 8000 children showed that parasite rates declined from 2.9% in 1949 to 0.2% in 1951 and spleen rates from 28.9% in 1949 to 5.9% in 1952. The number of deaths caused by malaria declined from 1357 in 1949 to just 138 in 1952 (see Table 1); over the same period, malaria-specific mortality fell from 29% to 3% *(20)*.

Table 1. Parasite rates, spleen rates and malaria deaths – Reunion, 1949–1952[a]

Year	Prevalence	Spleen rate	Total deaths	Deaths from malaria	Malaria-specific lethality
Before spraying					
1949	2.9%	28.9%	4690	1357	29%
During spraying					
1950	0.8%	19.0%	3319	943	28%
1951	0.2%	9.6%	2687	307	11%
1952	0.2%	5.9%	4622	138	3%

[a] *Source*: reference 20.

Spleen rates declined more slowly in the communes with the highest rates where three campaigns were often needed to reduce the rate to under 10% (see Table 2). By contrast, this objective was achieved after only one cycle of IRS in the two largest towns (Saint-Denis and Saint-Pierre).

Table 2. Spleen rate by commune – Reunion, 1950–1952[a]

Commune	March 1950	March 1951	March 1952
Bois Blanc	45,2%	23,5%	8,8%
La Possession	31,6%	64,9%	12,3%
Le Port	34,2%	17,4%	11,8%
Sainte-Rose	66,7%	16,5%	9,2%
Saint-Denis	29,4%	6,2%	1,0%
Saint-Gilles	60,3%	53,0%	26,9%
Saint-Paul	49,1%	30,6%	11,2%
Saint-Pierre	15,1%	1,6%	1,0%
Sainte-Anne	62,2%	41,2%	14,3%

[a] *Source*: reference 20.

From 1954 onwards, larval control was strengthened at the expense of IRS programmes, which were limited to the most receptive areas and then essentially discontinued in 1961. Only 26 cases of malaria were recorded between 1958 and 1964 *(1)*. Despite these highly satisfactory results, malaria transmission was not interrupted and the disease persisted, albeit at a low level, in some foci. WHO, which was involved in

the GMEP at the time, lent its support to the health authorities in order to develop and implement a phase of rigorous consolidation.

In 1965, a WHO mission was sent to Reunion. Surveillance was considerably strengthened in order to locate and clear up the last potential foci. Systematic examinations of blood donations were also carried out from this period onwards. Entomological surveillance was set up in 1966, with the study of adult behaviour and the location of 651 habitual *An. arabiensis* and *An. coustani* breeding places *(29)*.

Active case detection was implemented in 1966 with malaria testing in schools every 2–4 months. Health workers also took blood samples from febrile patients at their homes in areas where vector prevalence had formerly been high (between Sainte-Anne and Sainte-Rose and between La Possession and Saint-Gilles). These areas, with a population of around 60 000, were divided into seven operational sectors. Other areas were randomly selected for additional testing every month. These tasks were carried out by nine health workers and six specially trained microscopists.

Over a period of 20 months in 1966–1967, more than 17 000 blood slides were collected, meaning that nearly 20% of the population was under surveillance; two cases were identified. Six cases were identified by passive case detection among 8001 patients. It became routine procedure to test people in close contact with detected cases, and this led to the detection of a further case among 2133 blood samples. In addition, 22 000 slides were collected from schoolchildren and more than 12 000 blood donations were screened; no positive slides were found. The annual blood examination rate (ABER) was 6% (see Table 3). From the total of nine cases detected in the 20-month period, the annual parasite index was estimated at 0.012 per 1000.

The last three autochthonous malaria cases in Reunion were all identified in 1967 following extensive active case detection in the Cirque de Mafate caldera *(29)*.

Prevention of reintroduction since 1967

From 1968 onwards, active case detection efforts were gradually reduced and passive case detection was strengthened through implementation of a systematic case notification system. Between 1968 and 1972, five introduced and 36 imported cases were detected. Doctors became better informed and were encouraged to search for malaria cases. Thanks to passive case detection, ABER was maintained at around 5% (see Table 3). Registration and monitoring of travellers from endemic zones was implemented in 1971, which increased the number of imported cases detected; annual incidence was 0.03 per 1000 in 1972. Active case detection in homes was more or less discontinued in 1972, being limited to samples from people in close contact with imported cases *(7)*.

Although the last autochthonous cases were recorded in 1967, it was not until 1973 that the French government asked WHO to consider certifying elimination. Certification had just been granted to Mauritius. A WHO mission confirmed that local transmission had been interrupted, but noted that vulnerability levels remained high, with the danger of transmission becoming re-established in some areas of high receptivity. The mission judged that the surveillance and case-recording system was satisfactory with respect to the WHO standards in force. It also drew up a classification system for the communes according to their receptivity and vulnerability (see Table 4). Receptivity was determined on the basis of previous entomological observations; determination of vulnerability was based on the movements of travellers from malaria-infected areas and the distribution of imported cases in previous years. Malariogenic potential – a semi-quantitative measurement of the potential risk of re-establishment of transmission during the hot and rainy season, based on previous levels of vulnerability and receptivity – was also assessed *(7)* (see Figure 4).

Table 3. Malaria case detection – Reunion, 1968 –1972[a]

Year	Population	Active case detection	Passive case detection	ABER %	Detected cases
1966-1967[b]	417 701	17 976	8 001	6,2 %	9
1968	440 237	11 066	17 864	6,5 %	6
1969	453 444	10 717	8 294	4,1 %	1
1970	467 047	12 399	7 752	4,3 %	7
1971	479 087	6 549	15 976	4,5 %	13
1972	492 675	1 792	25 185	5,3 %	14

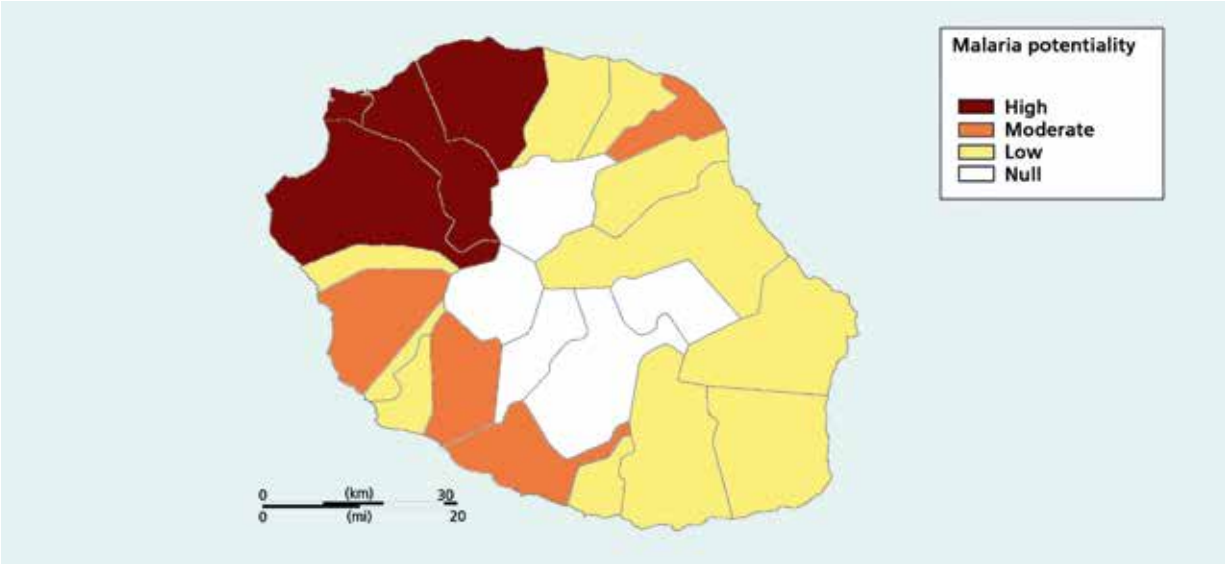
[a] *Source*: reference 7.
[b] *Data available for a period of 20 months.*

Table 4. Classification of communes in 1973 according to their previous levels of receptivity and vulnerability[a]

Arrondissement	Commune	Level of receptivity	Level of vulnerability	Malariogenic potential
Saint-Benoit	Saint-Benoit	++	+	Low
	Bras Panon	+	+	Low
	Plaine des Palmistes	0	+	Nil
	Saint-André	++	++	Moderate
	Sainte-Rose	+	+	Low
	Salazie	+	+	Low
Saint-Denis	Saint-Denis	++	+++	High
	Sainte-Marie	++	+	Low
	Sainte-Suzanne	+	+	Low
Saint-Paul	Saint-Paul	+++	+++	High
	Saint-Leu	+++	++	Moderate
	Le Port	+++	+++	High
	La Possession	+++	++	High
	Trois Bassin	+	+	Low
Saint-Pierre	Saint-Pierre	++	++	Moderate
	Avirons	+	+	Low
	Entre-Deux	+	+	Low
	Etang Salé	++	+	Low
	Petite Ile	+	+	Low
	Saint-Joseph	+	++	Low
	Saint-Louis	++	++	Moderate
	Saint-Philippe	+	+	Low
	Le Tampon	0	+	Nil
	Cilaos	0	+	Nil

[a] *Source*: reference 7.

Figure 4. Map of Reunion showing malariogenic potential by commune in 1973[a]



[a] *Map based on data from reference 7.*

A second WHO mission was sent to Reunion in 1978. It reiterated the conclusions of the previous mission and delivered its report to the Expert Committee on Malaria *(9)*, which advised the Director-General of WHO to add Reunion to the register of areas where malaria elimination had been achieved. This was done on 20 March 1979 and the French Minister of Foreign Affairs was notified by the Director-General.

Since 1973, the strategy for preventing reintroduction has been based exclusively on passive case detection and control of imported cases. Vector control has focused solely on systematic larval control activities guided by entomological surveillance (for details see the section on prevention of reintroduction, page 29). Indoor spraying has been carried out in only a few select areas, targeted as a result of entomological surveillance.

Since establishment of the centralized case register in 1967, no autochthonous cases have been reported (see Figure 1 and Annex 3). Investigations conducted in response to reports of malaria in people who had not travelled in the previous 12 months identified 23 cases contracted locally – four cases from transfusions and 19 introduced cases that were systematically and directly traced to an imported case (see below for details).

TRANSFUSION CASES

Since 1967, four transfusion cases have been identified: one in 1973 in a child of 13 years *(30)*, one in 1977 in a woman who had recently given birth *(5)*, and two other individual cases in 1984 *(31)*.

INTRODUCED CASES

In 1971, five introduced cases were detected together in children who had never left the island. The investigation concluded that they had probably been infected by anophelines from Malagasy immigrants living nearby *(30)*. Fourteen other introduced cases have been registered since that time, all involving people who had not left the island in the previous year; subsequent investigation in the neighbourhood linked them to a nearby imported case.

IMPORTED CASES

Between 1967 and 2010, 4205 imported cases were registered, most of which originated in Comoros or Madagascar. Of the 1849 cases reported between 1967 and 2000, 88% had been infected with malaria in one of the two neighbouring countries (see Table 5 and section on vulnerability, page 18).

From 1990 onwards, the number of imported cases from Madagascar declined sharply and was exceeded by the number from Comoros (see Figure 5).

Detailed data on the countries of infection since 2000 are unavailable, but the vast majority of cases registered between 2003 and 2009 continued to come from Comoros (52%) and Madagascar (28%) *(2)*.

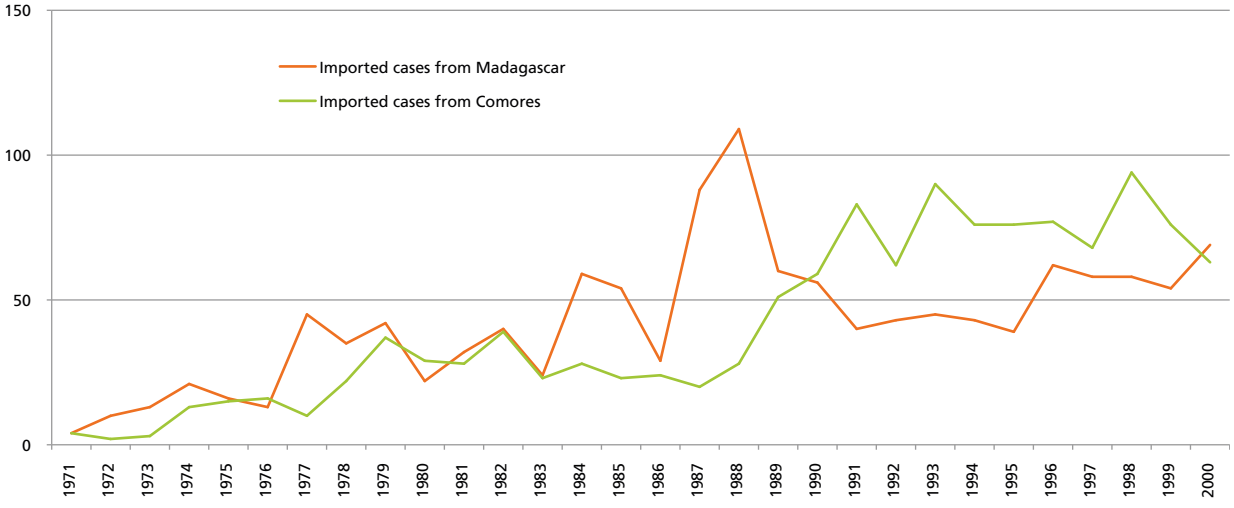
Table 5. Origin of infection of imported cases on Reunion, 1967–2000[a]

Origin of infection	No. of imported cases	%
Madagascar	1 293	44,9 %
Comoros	1 242	41,1 %
Mayotte	116	4,0 %
Mauritius	34	1,2 %
Africa	96	3,3 %
Asia	31	1,1 %
Unknown	70	2,4 %
Total	2 882	100,0 %

[a] *Source*: references 1, 3, 4–6, 8.

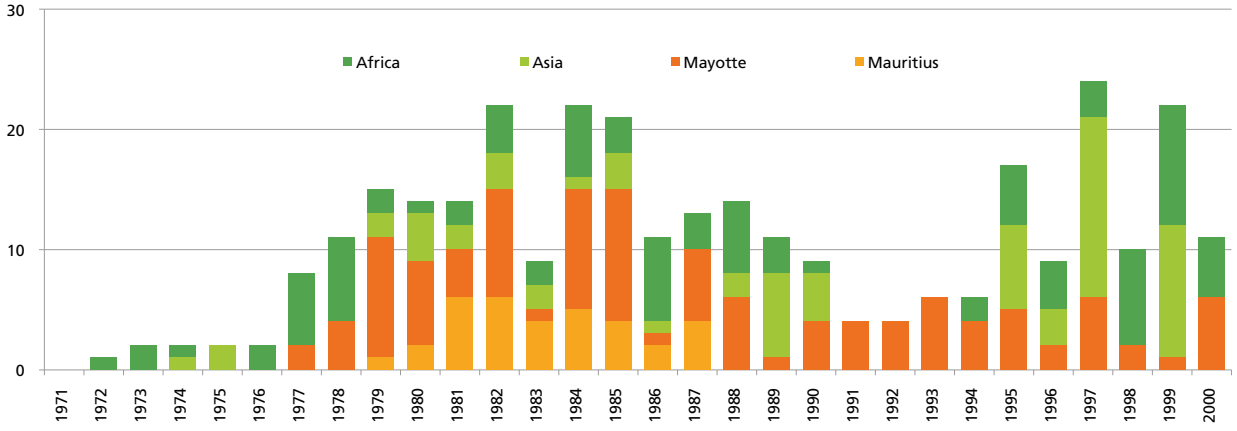
Other areas, such as Mayotte, Mauritius and some African and Asian countries, were also sources of infection. Despite large and increasing numbers of travellers, the number of cases imported from Mayotte remained relatively constant. The number of travellers between Reunion and Mauritius was also high; it is therefore no surprise that 34 cases contracted in Mauritius were registered in Reunion between 1975 (when transmission was re-established in Mauritius) and 1987 (the year in which transmission was once again interrupted). A small number of cases also came each year from malaria-infected areas on the African continent and in Asia (see Figure 6).

Figure 5. Number of imported cases from Madagascar and Comoros – Reunion, 1971–2000[a]



[a] *Source: references 1, 3, 4–6, 8.*

Figure 6. Number of imported cases from Mayotte, Mauritius, Africa and Asia – Reunion, 1971–2000[a]



[a] *Source: references 1, 3, 4–6, 8.*

Of the 171 cases of *P. falciparum* recorded in 1992–1994, 65% were detected in the two weeks following the arrival of the infected person. Cases caused by other species were less rapidly detected, with 41% being diagnosed after three months *(8)*.

Among the 312 cases registered between 2003 and 2004, 57% were taking no chemoprophylaxis and 34% were following a protocol that was inappropriate for the source country of infection *(32)*.

In general, Information on outcomes and mortality rates for imported cases of malaria is unavailable. Information is available only for the period 2003–2004 when it appears that 62% of the 312 cases recorded were admitted to hospital *(32)*.

The only published data on mortality come from the resuscitation unit at the Saint-Denis hospital. These show five serious cases of malaria treated between 1993 and 1996, with three resulting in death *(33)*. Another source cites seven deaths from malaria between 1992 and 1998 *(6)*.

FACTORS CONTRIBUTING TO THE CHANGED MALARIA SITUATION IN REUNION

How did malaria spread to the island?

It is unlikely that the vector was present before humans arrived on the island; certainly, malaria did not exist in Reunion before the middle of the 19th century. The disease appeared following a period of expansion in sugarcane monoculture at the beginning of the 19th century, for which large numbers of workers were brought from Europe, Africa and India. These workers may have introduced the parasite without actually causing local transmission initially. The cause of the sudden malaria epidemic that first hit Mauritius in 1865 and then spread to Reunion is difficult to explain fully. It is likely that a combination of factors triggered the epidemic and then favoured the long-term establishment of the disease. Deforestation for sugarcane cultivation and the influx of workers carrying the parasite may have been the main determining factors, but it is also possible that spread of the disease was the result of the introduction of steamship services, which could have carried the vector from the Madagascar coast in just two days *(21, 22)*.

How was malaria eliminated?

The process of elimination was protracted and difficult. In 1967, however, nearly 20 years after the first operations in 1949, the last autochthonous cases on the island were identified. Reunion, an island with a single vector (*An. arabiensis*) introduced just two centuries earlier, had achieved elimination on its coastline.

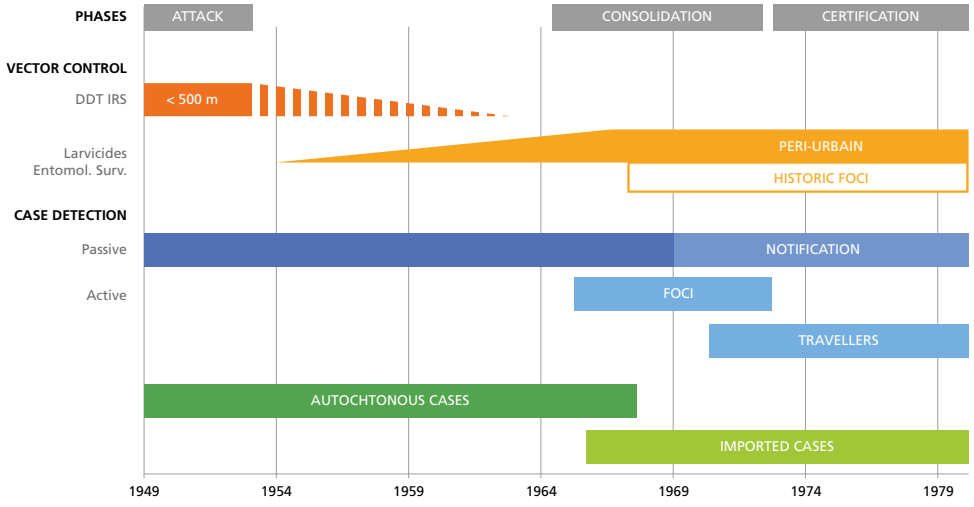
The humid tropical biotope was highly favourable to transmission, however, and elimination came at the price of substantial and costly vector control interventions. These interventions continue to the present day and include systematic larval control in possible introduction areas (points of entry such as ports and airports) and in areas where anophelines were present, and larval control and use of adulticides around imported cases where necessary.

The elimination of the last transmission foci was achieved in 1967 by following the sequential approach established by the GMEP (see Figure 7). The attack phase, consisting of widespread indoor spraying with DDT in regions less than 500 m above sea level, enabled the annual incidence to be reduced to a few rare cases in just four years. Larval control was then initiated within a 1-km radius of populated areas.

The consolidation phase was launched in 1967 following the recommendations of a WHO mission. This phase, which lasted until 1972, probably allowed the last autochthonous transmission foci to be cleared up through active case detection, including home visits and blood tests.

Entomological surveillance in high-risk zones was also established during the consolidation phase, together with compulsory notification of detected cases followed by case investigation.

Figure 7. Interventions implemented for the elimination of malaria, 1949–1979[a]



[a] *Graph by J.O. Guintran.*

Fluctuations in receptivity and vulnerability

RECEPTIVITY

In 1953, it was documented that *An. arabiensis* would begin to bite at dusk. Numbers of the vector were greatest at the end of the hot and rainy season during which it was observed in areas below 1200 m altitude. During the southern winter, larvae developed only in the low-lying plains (below 500 m), particularly in the irrigated agricultural areas around the coast *(20)*. The larval stage lasted 8–12 days in the hot season and 15–29 days in the cool season *(20)*.

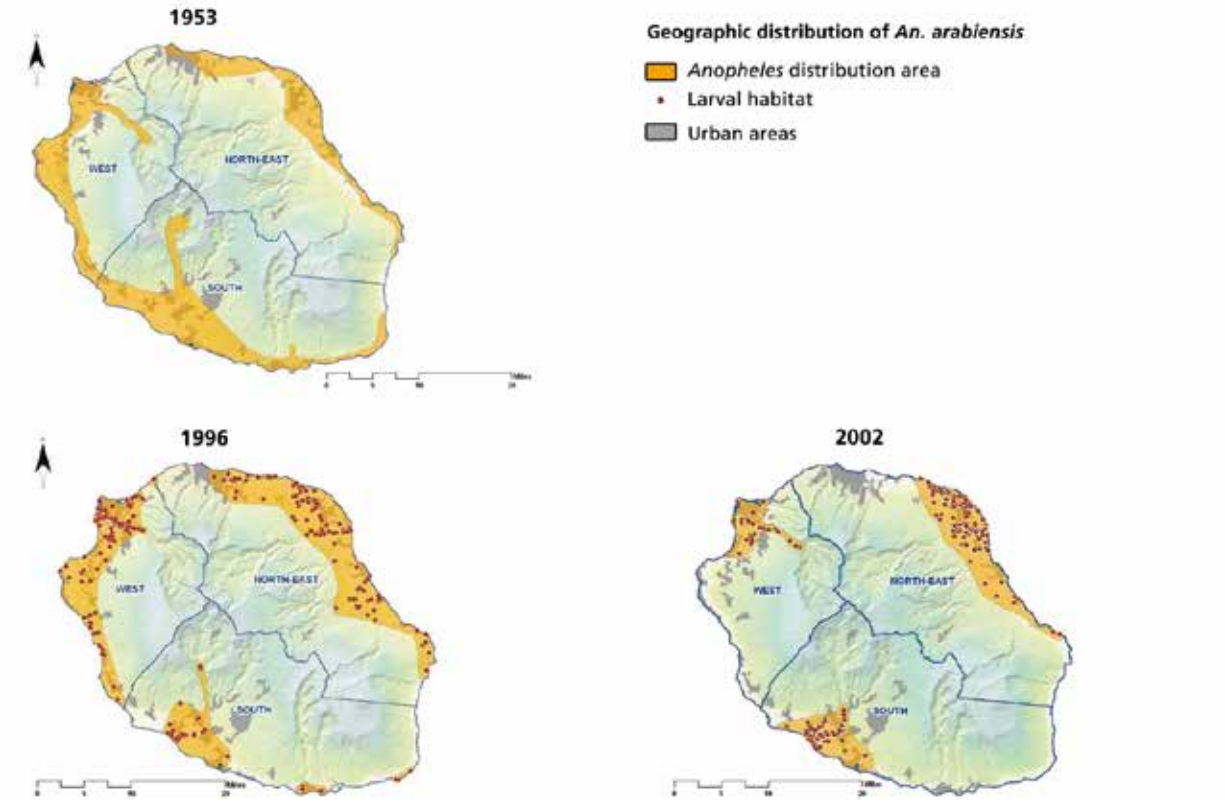
The behaviour and capacity of vectors were studied again in three separate areas of the island in 1997. Their lifespan exceeded 10 days only on rare occasions and exceeded 15 days only in the west at the end of the hot and rainy season. This short life expectancy inhibited the vectorial capacity of *An. arabiensis* and was a limiting factor for the re-establishment of transmission in Reunion. Receptivity also varied by area. In the east, the lower temperatures and the trade winds were unfavourable to proliferation of the vector during the southern winter; in the west, however, the climatic conditions ensured the presence of vectors throughout the year *(34)*.

An. arabiensis was manifestly endophilic before the start of the spraying campaigns; afterwards it developed more marked exophilic and exophagic tendencies while continuing to demonstrate anthropophilic behaviour *(20)*. This marked increase in exophilic behaviour was later confirmed *(34)*. The change, which was undoubtedly due to the pressure of IRS and of repellents used in dwellings, is commonly observed in *An. arabiensis (35)*. Progressive changes in habitat (more interior walls being smooth and light-coloured) may also have played a role in this development *(22)*.

In 1953, no breeding places were discovered that were far from dwellings. Later, however, it was observed that *An. arabiensis* females were laying their eggs further away following DDT application around homes. It therefore became necessary to extend larvicide treatment to a radius of 1 km from dwellings *(36)*.

Compared with observations made before the spraying campaigns of the 1950s *(28)*, the area of the *An. arabiensis* habitat seems to have been reduced. Between 1985 and 1987, the vector disappeared from certain coastal areas and seemed to persist in just three non-contiguous zones. In the past 15 years, the distribution of breeding places has changed once again: the breeding areas in the west and the north-east have been reduced considerably (see Figure 8) *(37)*. A distinct genetic structure has been identified in the three vector foci on the island, which implies the existence of obstacles to gene flow between the three separate areas of vector proliferation *(38)*.

Figure 8. Maps showing changing distribution of *An. arabiensis* on Reunion, 1953–2002[a]



[a] *Maps reproduced from reference 37 by kind permission of the author.*

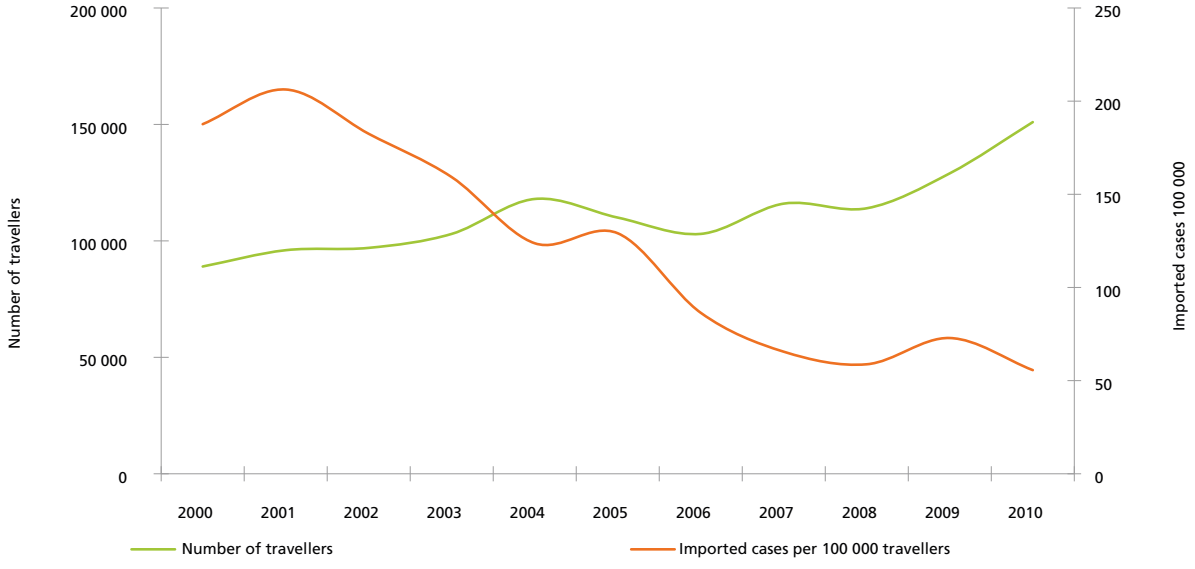
It is likely that receptivity persists today in the three non-contiguous areas in which the vector is present, whereas it is close to zero elsewhere. These areas extend between Saint-Paul and Le Port in the west, between Saint-Louis, Saint-Pierre and Saint-Philippe in the south, and between Sainte-Marie and Sainte-Rose in the east. The strengthening of larval control in peri-urban zones following the chikungunya epidemic of 2006 has resulted in further reductions in receptivity.

VULNERABILITY

Despite a steady rise in the number of travellers arriving from malaria-infected areas – from just 38 000 in 1977 *(39)* to 89 000 in 2000 and 151 000 in 2010 *(40)* – a reduction in the number of imported cases of malaria has been observed since 2000. The number of imported cases per 100 000 travellers has thus declined sharply (see Figure 9) *(2)*; in 2010, there were only 53 new cases of imported malaria per 100 000 travellers from endemic areas *(4)*. The incidence of imported cases varies greatly with the area of origin. In 2008, there were 1481 cases per 100 000 travellers arriving from Comoros, but only 37, 19 and 3 cases per 100 000 travellers arriving from Madagascar, continental Africa and Mayotte respectively *(2)*.

The majority of imported cases occurred among residents of the island returning from endemic areas. Between 1976 and 1981, 318 (85%) of 376 imported cases were residents of the island. Of these, 182 (57%) were born on the island or in metropolitan France, and the remaining 136 were recently-arrived immigrants from Comoros or Madagascar. Only 58 people were tourists. This distribution has changed little since that time: between 2003 and 2009, 86% of the 778 imported cases registered were residents of Reunion.

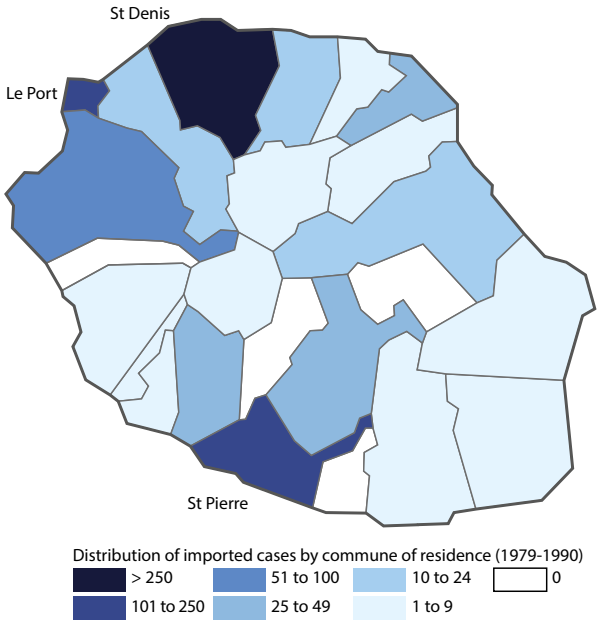
Figure 9. Number of travellers from endemic areas and incidence of imported cases per 100 000 travellers – Reunion, 2000–2010[a]



[a] *Graph based on data from reference 40, from ARS-OI, and from Regional Unit of the Institute for Public Health Surveillance.*

Vulnerability is strongly linked to population density, which is inevitably higher in the main urban areas where imported cases are more and more numerous. The distribution of imported cases on the island roughly mirrors population density. It is therefore unsurprising that the most cases are found in the main towns (see Figure 10): of the cases detected between 1979 and 1990, 43% were people living in the capital Saint-Denis, 20% in Le Port and 12% in Saint-Pierre *(1)*.

Figure 10. Distribution of imported cases by commune of residence, 1979–1990[a]



a Source: reference 1.

PREVENTION OF REINTRODUCTION: 1967 TO THE PRESENT

For more than 40 years, the island of Reunion has been successful in the difficult task of preventing new cases of autochthonous transmission. While certainly benefiting from being an island, Reunion has nonetheless faced both repeated introductions of *Plasmodium* sp. from neighbouring countries and the continued presence of a tropical African vector. This chapter describes the technical, logistic and legal means employed to ensure this success.

Organization

Laboratory work (slide reading, breeding and identification of mosquitoes) was performed in one centralized location, the Central Laboratory for Epidemiology and Hygiene, established in 1971. Once elimination had been achieved, the entomology department was absorbed into the vector control service of the ARS-OI; various medical and biological laboratories now carry out biological diagnostic work.

The total workforce engaged in antimalarial activities has varied over the past few decades. In 1973, 110 people were involved in malaria control on a part- or full-time basis, with plans for an additional 48 workers to be assigned to larval control in the following year *(7)*. In 1990, 165 people were working in malaria control, of whom 135 were assigned to vector control *(1)*. The number of workers then shrank progressively until the start of the chikungunya epidemic in 2005. As of 2012, the vector control service has had a stable workforce of 160 officials.

The vector control service was reorganized in the light of experience gained during management of the chikungunya epidemic of 2006, which affected 38% of the population. A public interest group was formed in October 2006 to coordinate work on the ground and harmonize government action relating to malaria and arbovirus vector control. As a result, the vector control service now targets not only *An. arabiensis* but also *Aedes albopictus*, the vector of dengue and chikungunya. It conducts entomological surveillance and also implements biological, mechanical and chemical interventions against adult vector mosquitoes and their larvae. The service has four disinfection and disease prevention centres, located in Saint-Denis, Saint-Paul, Saint-Pierre and Saint-Benoît, and works with border health control offices at the airports in Saint-Denis and Saint-Pierre and at Reunion's deep-water port. It also contributes to the monitoring of vector-borne illnesses in collaboration with the Regional Unit of the Institute for Public Health Surveillance (CIRE) and works to encourage public participation in preventive mosquito control.

Border health control services report to the ARS-OI health surveillance and emergency platform. The platform is composed of CIRE and the Health Surveillance, Alert and Administration Unit (CVAGS), which coordinate the epidemiological surveillance of malaria (a notifiable disease) in Reunion.

Legislation

The Public Health Code of Reunion specifies the measures to be taken to prevent the spread of certain diseases and establishes insect control, in particular, as mandatory. Prefectural Order No. 2966 of September 2007 defines a departmental mosquito control area and sets out, in general terms, the control measures to be taken in all 24 communes on the island. Every year, a prefectural order renews authorization for officials to enter and take equipment into public and private properties in all communes; this allows the officials to conduct surveys and treatment operations and to

undertake the actions and monitoring necessary for the control of mosquitoes and the diseases they transmit.

Autochthonous malaria is included on the list of 31 notifiable diseases throughout the territory of France. However, since the Decree of 11 December 1987, notification of cases of imported malaria is mandatory only in overseas departments such as Reunion.

Case detection and investigation

CASE DEFINITION

The official case definitions used in Reunion (and the rest of France) are the following:

Autochthonous malaria: clinical presentation of malaria associated with the presence of *Plasmodium* sp. on a thick or thin blood film, for cases in which the patient has not visited a malaria-endemic area in the 12 months preceding the first symptoms.

Imported malaria: clinical presentation of malaria, for cases in which patient has spent time in a malaria-endemic area, associated with the presence of *Plasmodium* sp. on a thick or thin blood film.

ORGANIZATION OF SURVEILLANCE

Since 1969, malaria surveillance has been based on mandatory notification. As soon as a case is diagnosed, it must be reported without delay, and control measures and an epidemiological investigation must be carried out immediately and systematically. The development of the epidemiological situation is then monitored by CIRE.

Cases of imported malaria are subject to mandatory notification only in the five French overseas departments (French Guiana, Guadeloupe, Martinique, Mayotte and Reunion). Case definitions are explained on the mandatory notification forms (see Figures 11a and 11b) distributed by the Institute for Public Health Surveillance (InVS) *(28)*.

When a malaria case is identified, officials from the vector control service visit the home of the infected person, conduct an epidemiological investigation to determine the origin of transmission, and evaluate the disease prevention measures taken, i.e. whether or not the appropriate antimalarial chemoprophylaxis was taken, compliance with treatment, vector protection measures used and compliance with these measures over time. The vector control service looks for vector breeding places in the infected person's home and in the 10 closest surrounding dwellings. They also distribute insecticide-treated bednets and carry out preventive work to reduce the risk of mosquito bites, as well as providing health education to family members of the infected individual.

The source of case notifications has changed over time. Out of 1198 recorded cases between 1979 and 1990, almost 64% *(762)* were notified through active case detection among travellers; the remainder were reported by health facilities *(1)*. Between 1992 and 1998, hospitals and clinics identified as many cases as were found through active case detection among travellers (37% of 992 reports). The remaining cases were reported by private laboratories (18%) and general practitioners (8%) *(6)*. The situation has changed considerably since the issue of health information messages advising travellers to go directly to public health facilities. Among cases reported between 2003 and 2004, 57% were notified by hospitals and clinics, 34% by laboratories outside of hospitals, and 4% by attending physicians. Active case detection among travellers, which by then was responsible for only 5% of reported cases, was abandoned in 2004 *(32)*.

Figure 11. Malaria notification forms[a]

(a) For imported malaria cases (English translation by WHO)

The French Republic

Reporting physician or biologist (stamp)	**If reported by biologist:**
Name:	**Name of clinician:**
Hospital/unit:	Hospital/unit:
Address:	Address:
Telephone:	Telephone:
Fax:	Fax:
Signature:	

Notifiable disease
Imported malaria in French overseas departments
cerfa 12204

Important: This disease requires urgent local, national or international intervention. **It must be reported, by any appropriate means (telephone, fax, etc.)**, to an ARS physician, even before receiving confirmation from the National Reference Centre (CNR) or before submitting this form.

Initial of last name: ☐ First name: .... Sex: ☐ M ☐ F Date of birth: |_|_|_|_|_|_|_|_|

Anonymous code: |_|_|_|_| |_|_|_|_| |_|_|_|_| |_|_|_|_| (*Assigned by ARS*) **Date of notification** |_|_|_|_|_|_|_|_|

Anonymous code: |_|_|_|_| |_|_|_|_| |_|_|_|_| |_|_|_|_| (*Assigned by ARS*) **Date of notification:** |_|_|_|_|_|_|_|_|

Sex: ☐ M ☐ F Year of birth: |_|_|_|_| Department of residence of patient: |_|_|_|

Imported malaria in French overseas departments

Criteria for notification: For residents of overseas departments only, presence of *Plasmodium* on a thick or thin blood film, patient has spent time in an area with endemic malaria.

Date of first clinical signs: |_|_|_|_|_|_|_|_|

Hospitalized: ☐ Yes ☐ No

Date of hospitalization: |_|_|_|_|_|_|_|_|

Location: ....

Clinical: Complications: ☐ Yes ☐ No

Outcome: ☐ Still affected ☐ Recovered

☐ Deceased Date of death: |_|_|_|_|_|_|_|_|

Diagnostic confirmation: Date of diagnosis: |_|_|_|_|_|_|_|_|

Plasmodium species: ☐ *P. falciparum* ☐ *P. vivax*

☐ *P. malariae* ☐ *P. ovale*

☐ Undetermined species: ....

If species other than *P. falciparum*, is it the patient's first infection by this species? ☐ Yes ☐ No

Has a strain sample been sent to the CNR for chemical resistance of malaria? ☐ Yes ☐ No

Has the case been reported to the CNR for imported and autochthonous malarial epidemiology? ☐ Yes ☐ No

Possible source of contamination:

For all periods of time spent in a malaria-endemic country, please list:

Country	Length of stay	Return date:
....	....	|_|_|_|_|_|_|_|_|
....	....	|_|_|_|_|_|_|_|_|
....	....	|_|_|_|_|_|_|_|_|
....	....	|_|_|_|_|_|_|_|_|
....	....	|_|_|_|_|_|_|_|_|
....	....	|_|_|_|_|_|_|_|_|

Reporting physician or biologist (stamp)	**If reported by biologist:**	**ARS (signature and stamp)**
Name:	**Name of clinician:**	
Hospital/unit:		
Address:	Hospital/unit:	
Telephone:	Address:	
Fax:	Telephone:	
Signature:	Fax:	

[a] *Source*: reference 4.

(b) For autochthonous malaria cases (English translation by WHO)

The French Republic

Reporting physician or biologist (stamp)	**If reported by biologist:**
Name:	**Name of clinician:**
Hospital/unit:	
Address:	Hospital/unit:
Telephone:	Address:
Fax:	Telephone:
Signature:	Fax:

Notifiable disease

Autochthonous malaria

cerfa 12203

Important: This disease requires urgent local, national or international intervention. **It must be reported, by any appropriate means (telephone, fax, etc.),** to an ARS physician, even before receiving confirmation from the National Reference Centre (CNR) or before sending this form.

Initial of last name: ☐ First name: .... Sex: ☐ M ☐ F Date of birth: |_|_|_|_|_|_|_|_|

Anonymous code: |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| *(Assigned by ARS)* **Date of notification:** |_|_|_|_|_|_|_|_|

- -

Anonymous code: |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_| *(Assigned by ARS)* **Date of notification:** |_|_|_|_|_|_|_|_|

Sex: ☐ M ☐ F Year of birth: |_|_|_|_| Department of residence of patient: |_|_|_|

Date of first clinical signs: |_|_|_|_|_|_|_|_|

Hospitalized: ☐ Yes ☐ No

Date of hospitalization: |_|_|_|_|_|_|_|_|

Location: ....

Clinical: Complications: ☐ Yes ☐ No

Outcome: ☐ Still affected ☐ Recovered

☐ Deceased Date of death: |_|_|_|_|_|_|_|_|

Autochthonous Malaria

Criteria for notification

1. Presence of *Plasmodium* on a thick or thin blood film; patient has not visited a malaria-endemic region in the 12 months preceding apparition of symptoms.
2. For residents of French Guiana, presence of *Plasmodium* on a thick or thin blood film; patient has not travelled outside the country in the 12 months preceding apparition of symptoms.

Diagnostic confirmation: Date of diagnosis: |_|_|_|_|_|_|_|_|

Plasmodium species: ☐ *P. falciparum* ☐ *P. vivax*

☐ *P. malariae* ☐ *P. ovale*

☐ Undetermined species: ....

If species other than *P. falciparum*, is it the patient's first infection with this species? ☐ Yes ☐ No

Has a strain sample been sent to the CNR for chemical resistance of malaria? ☐ Yes ☐ No

Has the case been reported to the CNR for imported and autochthonous malarial epidemiology? ☐ Yes ☐ No

Possible source of contamination:

Blood transfusion: ☐ Yes ☐ No If yes, specify: Hospital: .... Date: |_|_|_|_|_|_|_|_|

Transplant: ☐ Yes ☐ No If yes, specify: Hospital: .... Date: |_|_|_|_|_|_|_|_|

Type of transplant: ....

Accidental exposure to blood: ☐ Yes ☐ No

Congenital: ☐ Yes ☐ No

Intravenous drug use: ☐ Yes ☐ No

Airport zone:

Residence in an airport zone (e.g. hotel): ☐ Yes ☐ No If yes, specify: ....

Residence in a commune adjacent to an airport: ☐ Yes ☐ No If yes, specify: ....

Employed in an airport: ☐ Yes ☐ No If yes, work location: ....

Work description: ....

Time spent in an airport: ☐ Yes ☐ No Location: ....

Received package, luggage or container sent from endemic area: ☐ Yes ☐ No

If yes, date: |_|_|_|_|_|_|_|_| Country of origin: ....

- -

Reporting physician or biologist (stamp)	**If reported by biologist**	**ARS (signature and stamp)**
Name:	**Name of clinician:**	
Hospital/service:		
Address:	Hospital/service:	
Telephone:	Address:	
Fax:	Telephone:	
Signature :	Fax:	

Notifiable disease (Art L 3113-1, R 3113-1, R 3113-2, R 3113-5, D 3113-7 of Public Health Code)

Personal information – Rights of access and rectification for 6 months by reporting physician (Law of 6 January 1978) – Information centralized at the Institute for Public Health Surveillance (InVS)

[a] *Source*: reference 4.

Disease treatment

In 1973, malaria patients were treated with chloroquine for five days *(30)*. Carriers of *P. falciparum* gametocytes and patients infected with *P. vivax* or *P. ovale* also received radical treatment with 8-aminoquinolines *(7)*. As *P. falciparum* has developed resistance, treatments have since been adapted and continue to be developed in accordance with the recommendations of experts.

Until 2005, border health control officials at the Saint-Denis airport collected forms filled out by travellers arriving from mainland Africa, Comoros, Madagascar and Mayotte. The forms required travellers to specify their name, the countries they had visited, and their address and contact number on the island. This information was then transmitted to the disease prevention service, located in four centres spread throughout the island. The service was tasked with contacting travellers by telephone to inform them of risks, enquire about their compliance with chemoprophylaxis and offer free check-ups in case of fever *(42)*. In 1988, Mauritius ceased to be considered an at-risk area, and from 1993 onwards forms were given only to travellers who had spent time in Comoros, Madagascar or Mayotte *(8)*. The system detected less than 5% of cases in the 2000s and was finally abandoned in 2006.

Today, information is provided to travellers by various means, such as posters at the airports. *Any person* having travelled abroad and showing signs of infection within seven days is instructed to consult a general practitioner.

Entomological surveillance

Entomological surveillance consists of the systematic investigation of all vector breeding places registered by vector control service officials. Data are recorded in a geographic information system in which several distinct areas of activity have been defined.

Weekly investigations are conducted in 109 surveillance areas that cover the current distribution range of the vector. In 2012, 425 breeding places for *An. arabiensis* were identified and treated through this system (see Figure 12).

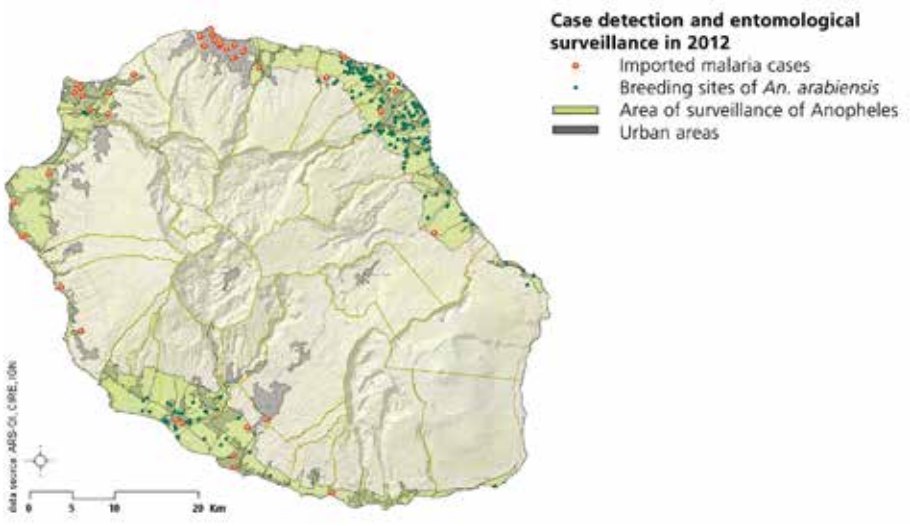
In accordance with the 2005 International Health Regulations, vector control is strengthened within 400 metres of port and airport facilities. The vector control service carries out visits to all private and public properties (dwellings and business premises) surrounding these points of entry to look for vector breeding places, and also publishes recommendations for controlling risk.

Vector control

The vector control service continues to target *An. arabiensis,* and now also *Aedes albopictus* – the vector of dengue and chikungunya. The control programme for *An. arabiensis* is essentially based on rigorous larval control in targeted areas and individual interventions when imported cases arise. Breeding places that have already been registered and mapped are sprayed with insecticide every 10–15 days. In the past, temephos was used, either as 1% granules or as a 500 g/L solution applied with pre-pressurized sprayers *(1)*.
Following adoption of the European Biocidal Products Regulation, temephos was replaced with a biological control agent (*Bacillus thuringiensis israelensis*, or Bti) after a brief period during which French overseas departments were exempted *(44)*.

Currently, the measures taken against adult vectors are limited to deltamethrin spraying of dwellings neighbouring those of individuals infected with imported malaria. The vector control service continues to monitor vector resistance to insecticides (adulticides and larvicides) in its entomology laboratory.

Figure 12. Map of surveillance areas for *An. arabiensis*, breeding places, and imported cases – Reunion, 2012[a]



[a] *Source*: reference 43.

ARS-OI and border health control officials are also responsible for ensuring that aircraft and ships are free of insects, in accordance with the international legislation in force.

A four-year feasibility study is currently being carried out to assess whether the sterile insect technique is a viable option for controlling *An. arabiensis* and *Ae. albopictus* in Reunion *(45)*. Results so far indicate that the procedure is feasible, and discussions on implementation on the ground are still under way.

Health education

Travel agencies and airlines based in Reunion distribute information leaflets on the risk of malaria and preventive measures *(8)*. The recommended preventive medicines (atovaquone–proguanil, doxycycline, mefloquine) are widely available in pharmacies, although most are not covered by health insurance. At the airports, posters alert travellers to the presence of vectors in Reunion and remind them of the importance of consulting a physician immediately if they notice signs of infection. A specialized medical centre for travellers exists, but its activities are limited.

The vector control service is also in charge of informing the public about the risk of malaria and the preventive measures available. A variety of activities – social mobilization, demonstrations, and meetings – are organized to inform the population about mosquito biology and related diseases, and about protective and preventive measures. Information materials are distributed, public educators trained and communication campaigns organized. A free hotline – *Ensemble contre les moustiques* (United against mosquitoes) – responds to enquiries and records reports of mosquito nuisance and situations in which there is a risk of nuisance (see logo, Figure 13). The hotline received 1783 calls in 2008. The public can also consult an information website *(43)*. In 2008, the vector control service distributed 50 000 pamphlets explaining protective and preventive measures and 1300 comic strips on the life-cycle of the mosquito, and on vector-borne diseases and their transmission. Posters designed to increase awareness are displayed in many public places, and a radio campaign on protection around the home and the importance of cooperating with vector control service officials has also been launched.

The cost of preventing reintroduction

In 1990, the annual cost of malaria control was US$ 3 350 000, or US$ 6 per inhabitant[1], which represented 0.65% of the island's total health care budget. More than three-quarters of funds went to vector control *(1)*.

Information on the costs associated with the prevention, early treatment, and surveillance of imported cases is unavailable. Resources devoted to vector control increased following the chikungunya epidemic of 2006, reaching approximately US$ 14.60 per inhabitant in 2012. This figure may seem disproportionate when compared with the US$ 2.40 per inhabitant spent by Mauritius between 1990 and 2008 *(46)*, but it is worth noting that only a small proportion of Reunion's vector control budget is allocated to malaria control, given that the vector control service principally targets the vectors of arboviruses. Only eight of the 160 officials in the service are involved in antimalarial activities.

Figure 13. Public information campaign logo of ARS-OI[a]

[a] *Source*: reference 44.

[1] Current value *(2013)*: US$ 10.70 (source: http://www.usinflationcalculator.com/).

LESSONS LEARNED AND DRIVERS OF CHANGE

Political commitment, effective methods and strict implementation of Global Malaria Eradication Programme strategies

France began working towards eradicating malaria in Reunion at the end of the Second World War. With the island having been made a French department in 1946, the moment was ripe for strong political commitment in the region. A second important factor was the availability of DDT, which had recently proved to be extremely effective against anopheline vectors of malaria in temperate climates. The third and deciding factor in the achievement of elimination was the launch in 1955 of the GMEP, which advocated a sequential, strategic approach and provided effective methodological tools for implementing interventions.

Strict prevention of reintroduction

ENTOMOLOGICAL SURVEILLANCE AND VECTOR CONTROL

Although it has proved possible to limit the vectorial capacity and geographical spread of vector mosquitoes in Reunion, their complete eradication with the means currently available is impracticable. A vector control strategy concentrating exclusively on breeding places and guided by entomological monitoring has been effective in limiting the vectorial capacity of mosquitoes (which became exophilic following indoor spraying of DDT). Use of data from epidemiological and entomological monitoring to focus interventions geographically was probably crucial in avoiding renewed transmission, once the widespread IRS campaigns had ended.

Larval control requires strict organization and extensive human resources. Despite its high cost, it is considered essential in permanently and responsively constraining the vectorial capacity of vectors on the island *(47)*. Total eradication of the vector is not yet achievable, but it has been possible to lower vectorial capacity, limit spread and prevent new cases of autochthonous transmission.

Operational research in Reunion benefits from the presence of experts from a branch of the French Institute for Research and Development and the Indian Ocean Research and Surveillance Centre (a research centre for emerging infectious diseases). These organizations develop and support several projects for eradicating local vectors (*An. arabiensis* and *Ae. albopictus*) through the use of various sterilization techniques.

CONTROLLING THE RISK OF *PLASMODIUM* SP. IMPORTATION

Continued instances of imported parasites in Reunion have necessitated measures that target travellers arriving from endemic areas. The annual rate of imported infections, which is considered a measure of vulnerability, currently stands at 0.12 cases per 1000 inhabitants. Although this is much lower than the rate recently recorded in Zanzibar *(48)*, it has nonetheless led to a small number of introduced cases over the past 30 years. Reunion does not practise active case detection for such cases; instead, individuals who have recently travelled and are experiencing fever symptoms are recommended to consult their attending physician. Health professionals immediately report cases as part of the mandatory notification protocol. This system of passive detection, paired with mandatory notification of cases identified by laboratories and health facilities, has been critical. Since 1967, it has enabled an immediate and systematic epidemiological investigation to be conducted in the area surrounding imported cases; subsequent interventions aimed at preventing secondary transmission are then implemented if necessary.

It is very likely that a small number of infections go undetected, particularly among immunized adults recently arrived from endemic areas, who remain asymptomatic. Likewise, certain relapses of *P. vivax* can cause short, non-serious bouts of fever which may go unreported The risk associated with such cases is limited given the low proportion of *P. vivax* in Comoros and Madagascar, where most imported cases originate. As has been observed in Mauritius, however, renewed transmission restricted to *P. vivax* is possible, given that its life-cycle is shorter than that of *P. falciparum*.

Since the 1970s, monitoring of travellers arriving from endemic areas has been reduced. Surveillance measures are largely limited to passive case detection through mandatory case notification, followed by a routine home investigation. Between 2005 and 2008, Mauritius received more at-risk travellers (175 000 on average) than Reunion (110 000), but detected far fewer cases (36 cases per year compared with 94) *(46)*. However, these statistics give no indication of the respective performances of each system, as the risks are not at all comparable. Reunion's situation is unique in that the island receives large numbers of travellers from Mayotte, and Comorian immigrants make frequent return trips made to Comoros - and these two groups have a risk of infection six times higher than that of travellers arriving from other areas *(2)*.

RISK PREVENTION FOR TRAVELLERS

The number of imported cases per 100 000 at-risk travellers has dropped by nearly 75% since 2001, with only 56 cases reported in 2010. The majority of imported cases are residents of the island. This decline is probably the result of improved information on the preventive measures available to those travelling to destinations with a malaria risk, but is also attributable to lower transmission rates in the sub-region. Use of insecticide-treated bednets and, in the past 10 years, of chemoprophylaxis (atovaquone–proguanil and doxycycline) to which *P. falciparum* is less resistant has also played a role. The proportion of imported cases involving individuals who did not take any form of chemoprophylaxis (57%) does not seem to have changed between 2003 and 2008 *(2, 32)*. The risk posed by travellers arriving from Madagascar has dropped significantly since 2005, the year in which malaria control programmes in that country began to be successful *(49)*. Increased prevention efforts are still needed to reduce the risk of infection among travellers arriving from Comoros *(2)*.

Outlook

One question remains for any region that has achieved elimination and is attempting – through action that sometimes requires significant resources – to prevent reintroduction: will it ever be possible to terminate these efforts without having completely eradicated the vector? Reunion, which has significantly reduced vectorial capacity over the past few decades, is an interesting case. This reduction is probably due to a number of factors but may be attributed principally to increased economic development, which has led to improvements in housing and land use, public health, surveillance and response. The ecology of the vector is very specific in Reunion: vectors are confined to smaller and smaller ecological areas, which limits the risk of malaria spreading. Nevertheless, the situation should continue to be closely monitored.

The fact that Reunion is a relatively isolated island also plays a fundamental role in terms of vector control by reducing significantly the risk of reintroduction of vectors.

Introduced cases recorded as recently as 2005 and 2006 seem to indicate that a very real risk of renewed autochthonous transmission remains in Reunion. It is therefore difficult to imagine abandoning efforts to prevent both the importation of parasites and secondary transmission from imported cases. Given the constant circulation of people between Reunion and neighbouring territories, malaria control programmes on the island must be integrated in a region-wide effort that includes all islands in the south-west Indian Ocean.

CONCLUSION

Reunion reported its last indigenous case of malaria in 1967 and received official certification of malaria-free status in 1979. Since then, the island has been permanently at the stage of preventing reintroduction, which requires strict entomological and epidemiological surveillance, preventive measures and public information campaigns (especially for travellers), in addition to deployment of multidisciplinary response teams.

The enthusiastic response to recent successes in malaria control should encourage several African countries to work towards elimination. This report will allow others to draw on Reunion's experience and learn from this rare example of successful implementation of the interventions and strategies advocated by the GMEP and carried out in a small island territory with a tropical climate and a typical African vector. The information on prevention of reintroduction, which has been collected and analysed in this report, is also extremely valuable and could guide the development of similar programmes in regions where local transmission has recently been interrupted.

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ANNEX 1: DATA SOURCES AND METHODS APPLIED

A review of the literature was conducted on PubMed (United States National Library of Medicine) using the key words "malaria" "Reunion island" "elimination" and "eradication". Mission reports related to the island of Reunion came from WHO headquarters archives. Various documents and reports taken from the websites of institutions based in Reunion or mainland France were also used. Epidemiological data from the various documents were compiled in a computerized spreadsheet and presented – along with certain key indicators – in the form of tables and maps.

ANNEX 2: POPULATION

Table A2.1 Population of Reunion by arrondissement and by commune, according to the 2008 population census[a]

District	Town	Population
Saint-Benoît		**118 124**
	Bras-Panon	11 511
	Saint-André	53 310
	Salazie	7 366
	Sainte-Rose	6 880
	Saint-Benoît	34 021
	La Plaine-des-Palmistes	5 036
Saint-Denis		**199 581**
	Saint-Denis	145 776
	Sainte-Marie	31 204
	Sainte-Suzanne	22 601
Saint-Paul		**209 421**
	Saint-Leu	30 207
	Saint-Paul	104 384
	Le Port	38 564
	La Possession	29 175
	Les Trois-Bassins	7 091
Saint-Pierre		**289 875**
	Les Avirons	10 503
	Saint-Philippe	5 168
	Cilaos	6 090
	Entre-Deux	6 104
	L' Étang-Salé	13 555
	Petite-Île	11 813
	Saint-Joseph	35 493
	Saint-Louis	51 181
	Saint-Pierre	77 031
	Le Tampon	72 937

[a] *Source*: Demographic situation in Reunion in 2009. Paris: French National Institute for Statistics and Economic Studies; 2011.

ANNEX 3: PARASITES AND VECTORS

Parasites prior to elimination

A prevalence investigation conducted among children before the first DDT spraying campaigns in 1949 revealed that *P. vivax* was predominant over *P. falciparum*, with a small proportion of *P. malariae* (see Table A3.1). Investigations conducted after spraying had started showed a predominance of *P. falciparum*, which tended to decrease each year *(1)*.

Table A3.1 Distribution of species detected on positive slides from prevalence investigations carried out before and after spraying started, 1949–1952[a]

Year	Tested	Positive	*P. falciparum*	*P. vivax*	*P. malariae*
Before spraying					
1949	2 322	67	19 (28%)	44 (66%)	4 (6%)
During spraying					
1950	8 993	72	58 (80%)	6 (8%)	8 (11%)
1951	7 164	16	11 (69%)	5 (31%)	
1952	9 312	17	9 (53%)	6 (35%)	2 (12%)

[a] *Source*: reference 1.

Imported parasites

The distribution of species appears to reflect the prevailing situation in the main countries of origin (Comoros, Madagascar), where *P. falciparum* is the predominant species. Out of 207 imported cases between 1972 and 1977, 86% (179 cases) tested positive for *P. falciparum*, and 10% (20 cases) were infected exclusively with *P. vivax*. The remaining 4% were infected with *P. ovale* or *P. malariae (2)*. Similarly, for the 1198 cases recorded between 1979 and 1990, close to 86% (1012 cases) tested positive for *P. falciparum*, while 12% (138 cases) were infected exclusively with *P. vivax*. The remaining 2% were infected with *P. ovale* or *P. malariae (3)*. Of the 778 imported cases recorded between 2003 and 2009, 84% were infected with *P. falciparum (4)*.

Vectors

The non-vector species *An. coustani* and *An. costalis* were the first to be documented on the island *(5)*. Doubts remain as to whether *An. arabiensis* or *An. funestus* were already present *(6)*. It is possible that the latter was present and then disappeared once DDT spraying began *(1)*. The presence of *An. merus*, which is adapted to brackish water and has been observed in Mauritius, has been suspected but also remains unconfirmed *(6)*. Large numbers of *An. arabiensis* were identified and studied around the entire coastline in the early 20th century. Distinguishing the different species – through cytogenetic methods – became possible only in 1960, after the widespread spraying campaigns. Since then, only *An. arabiensis* has been observed. The discovery of sporozoites in the salivary glands of two adults in 1971 confirmed the vectorial capacity of this species, just before transmission was interrupted *(7)*. The only two *Anopheles* species observed in 1997 were *An. coustani* and *An. gambiae* s.l., with all specimens of

the latter belonging to the species *An. arabiensis (8)*. *An. arabiensis* is therefore considered to be the only vector currently present on the island of Reunion. When the genetic profiles of *An. arabiensis* from Madagascar, Mauritius and Reunion were compared, significant differences were found between the three populations *(9)*.

Breeding places are found mainly in the bottom of ravines formed by rivers with irregular flow-rates, in pools surrounding coastal ponds, small marshy areas on the coastal plains, pools dug for irrigation in vegetable fields and standing water near roadsides or by constantly-flowing fountains *(1)*. Two types of biotope were observed in 2008. The first comprises holes in rocks, residual standing water, or sheltered coves in ravines, and the second pools left by rainfall, irrigation systems, or sprinkler systems in sugarcane fields or on field roads *(10)*.

Testing conducted in 1966 showed DDT to be fully effective against *An. arabiensis (11)*. In 1973, tests showed larvae to have developed a certain level of resistance to DDT, while adults still seemed to have no resistance *(7)*.

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ANNEX 4: REPORTED CASES 1967–2010

Table A4.1 Autochthonous, transfusion-transmitted, introduced and imported cases, 1967–2010[a]

Year	Autochthonous cases	Induced cases	Introduced cases	Imported cases	Total cases
1967	3			3	3
1968				5	5
1969				1	1
1970				7	7
1971			5	8	13
1972				14	14
1973		1		18	19
1974			1	38	39
1975			2	36	38
1976				32	32
1977		1	1	67	69
1978			1	75	76
1979			2	97	99
1980			1	66	67
1981				74	74
1982				103	103
1983				57	57
1984		2	1	110	113
1985				100	100
1986				64	64
1987			1	123	124
1988			1	155	156
1989				122	122
1990				127	127
1991				153	153
1992				119	119
1993				153	153
1994				127	127
1995				132	132
1996				148	148
1997				151	151
1998				163	163
1999				153	153
2000			1	167	168
2001				198	198
2002				177	177

Year	Autochthonous cases	Induced cases	Introduced cases	Imported cases	Total cases
2003				164	164
2004				146	146
2005			1	142	143
2006			1	89	90
2007				76	76
2008				67	67
2009				94	94
2010				84	84

[a] *Source*: data compiled from references 1–9.

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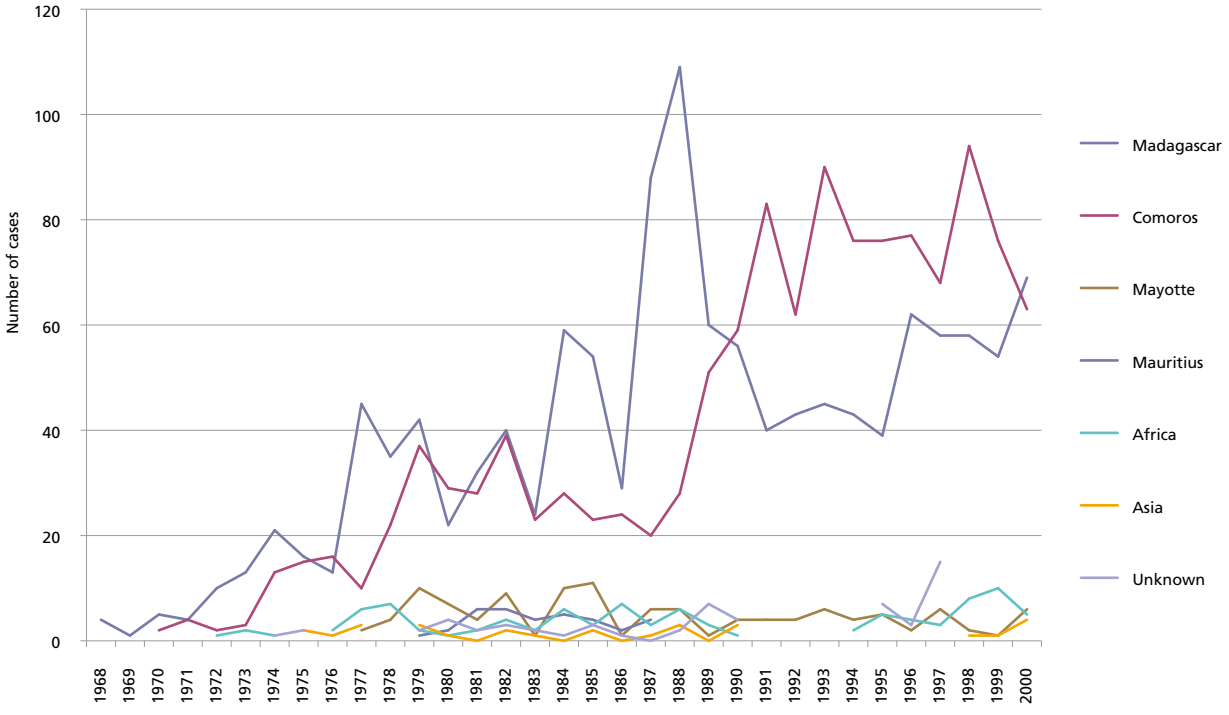
ANNEX 5: IMPORTED CASES AND SOURCES OF INFECTION 1967–2000

Table A5.1 Cases of imported malaria by country or area of origin, 1967–2000[a]

Year	Total	Madagascar	Comoros	Mayotte	Mauritius	Africa	Asia	Unknown
1967	3							
1968	5	4	1					
1969	1	1						
1970	7	5	2					
1971	8	4	4					
1972	14	10	2			1	1	
1973	18	13	3			2		
1974	38	21	13			1		1
1975	36	16	15				2	2
1976	32	13	16			2	1	
1977	67	45	10	2		6	3	
1978	75	35	22	4		7		
1979	97	42	37	10	1	2	3	2
1980	66	22	29	7	2	1	1	4
1981	74	32	28	4	6	2	0	2
1982	103	40	39	9	6	4	2	3
1983	57	24	23	1	4	2	1	2
1984	110	59	28	10	5	6	0	1
1985	100	54	23	11	4	3	2	3
1986	64	29	24	1	2	7	0	1
1987	123	88	20	6	4	3	1	0
1988	155	109	28	6		6	3	2
1989	122	60	51	1		3	0	7
1990	127	56	59	4		1	3	4
1991	153	40	83	4				
1992	119	43	62	4				
1993	153	45	90	6				
1994	127	43	76	4		2	2	
1995	132	39	76	5		5		7
1996	148	62	77	2		4		3
1997	151	58	68	6		3		15
1998	163	58	94	2		8	1	
1999	153	54	76	1		10	1	11
2000	167	69	63	6		5	4	

[a] *Source*: references 1–9.

Figure A5.1 Imported cases by country or area of origin, 1967–2000[a]



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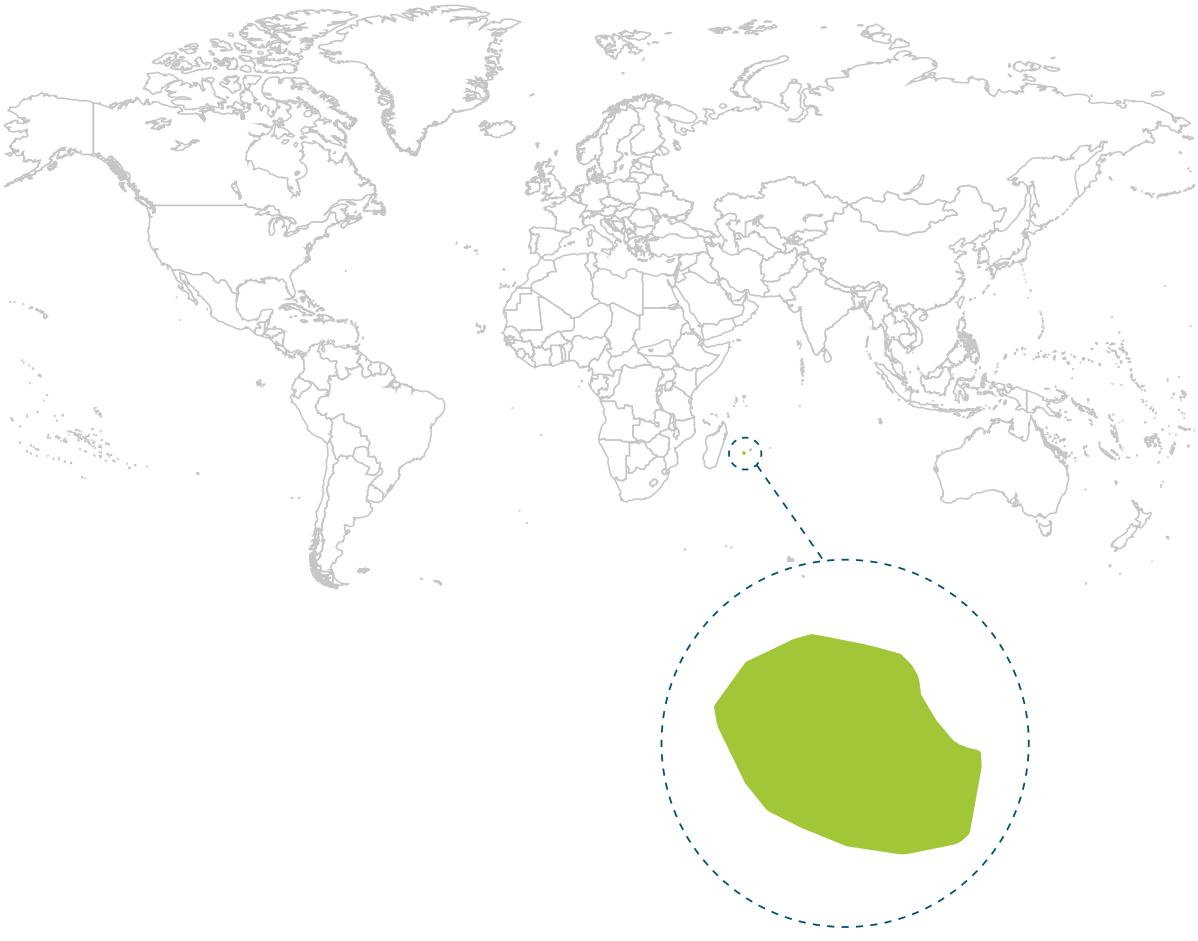

This case-study is part of a series of malaria elimination case-studies conducted by the World Health Organization (WHO) Global Malaria Programme and the University of California, San Francisco (UCSF), Global Health Group. The case-studies series documents the experience gained in eliminating malaria in a range of geographical and transmission settings with the aim of drawing lessons for countries that are embarking upon elimination.

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