ENVIRONMENTAL CHANGE AND MALARIA RISK

Global and Local Implications

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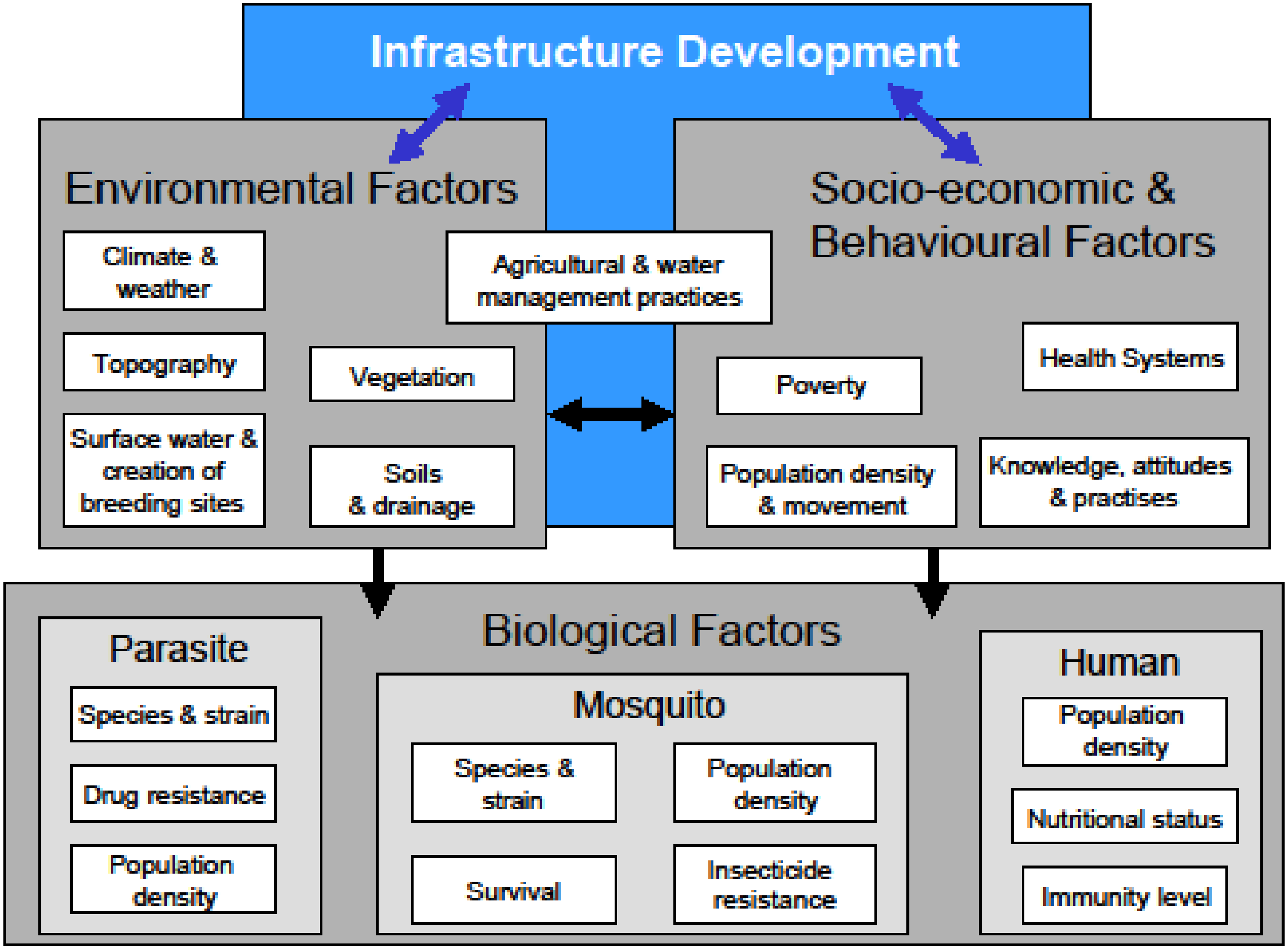
ENVIRONMENTAL PROBLEMS

- Air Quality
- Pollution
- Toxicity
- Destruction of Ozone Layer – first global problem?
- Destruction / Change of ecosystem
- Population Expansion / Infrastructure

Figure 2. Contextual determinants of malaria, modified from[12]



MALARIA EPIDEMICS

- Occurs in areas of unstable malaria transmission
- When environmental conditions favourable

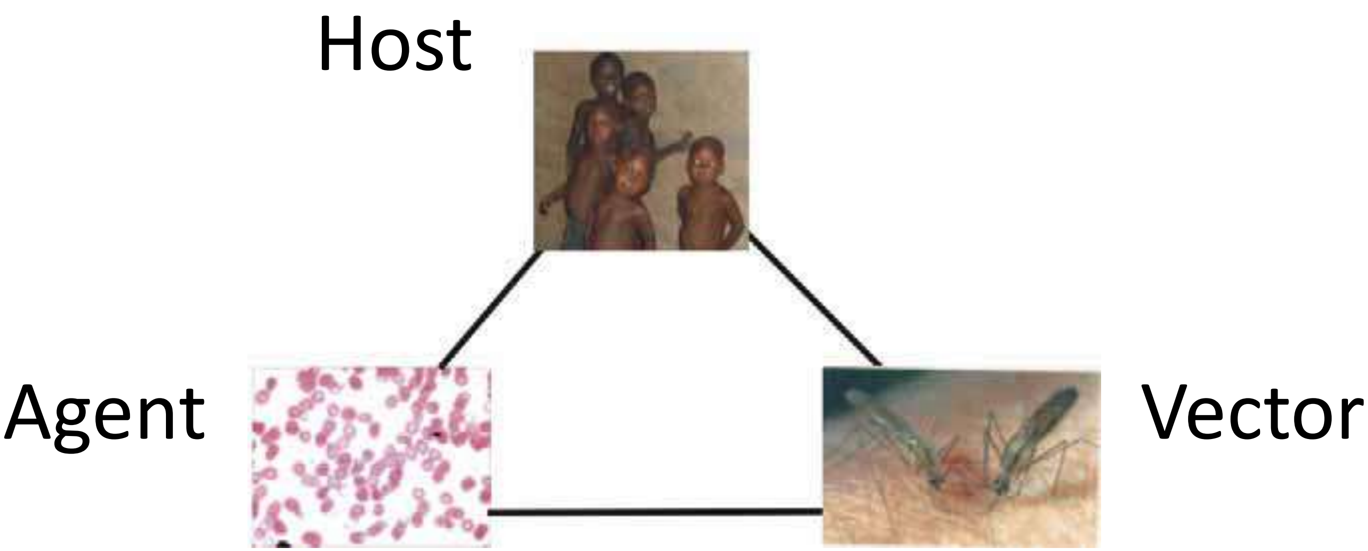
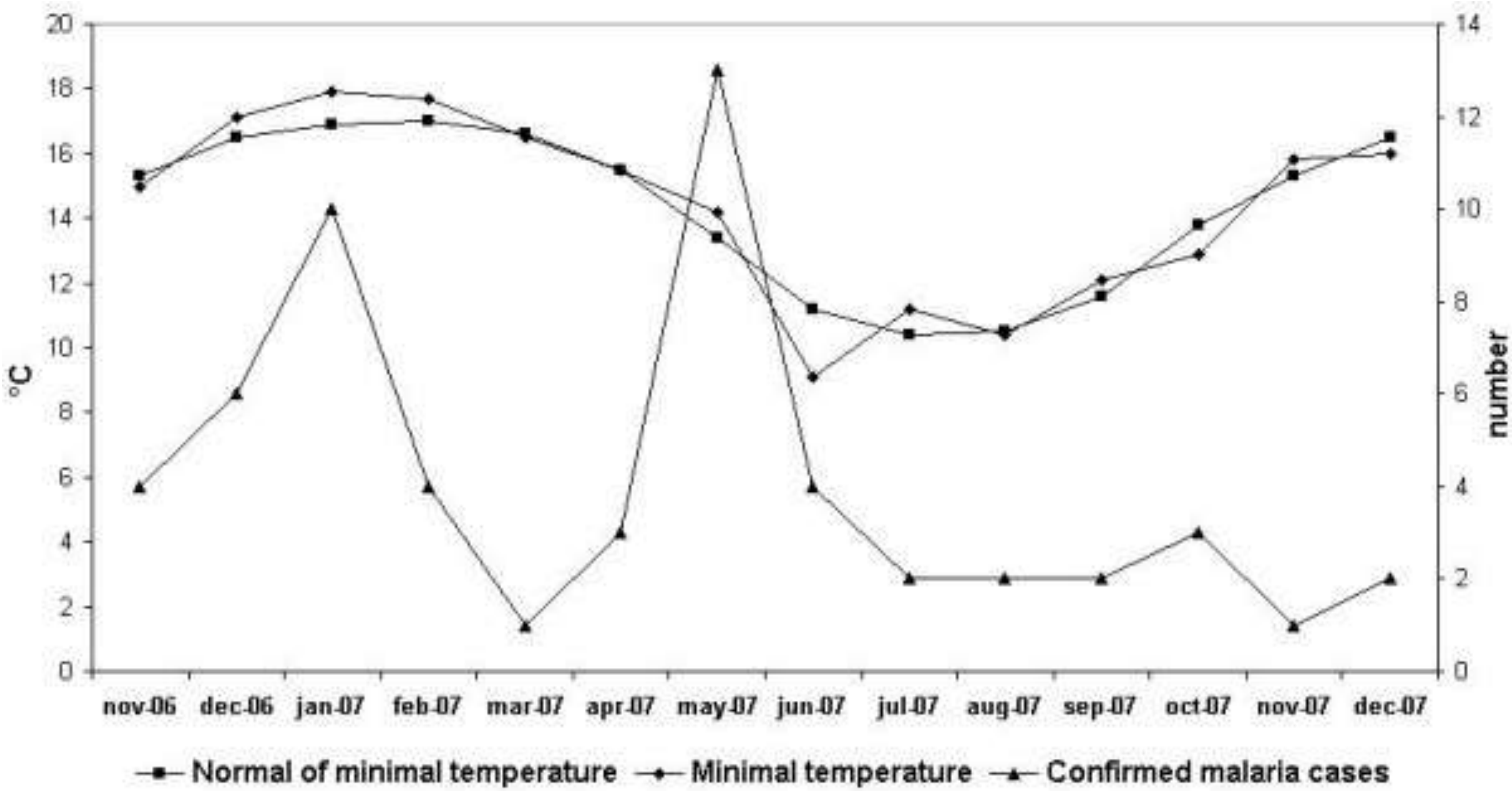


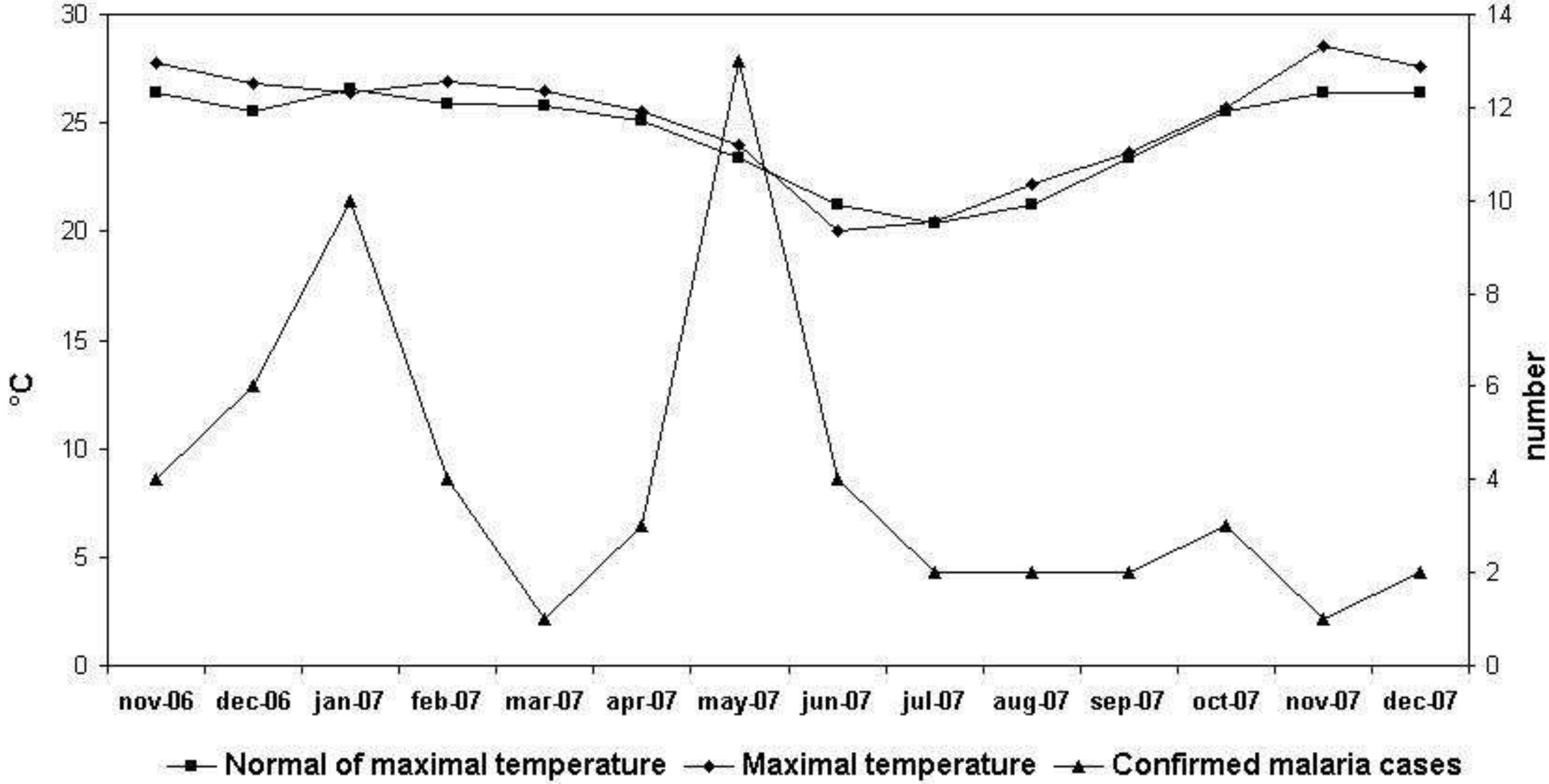
Table 1. Examples of models developed to predict malaria epidemics and assess malaria risk in relation to environmental change. Input data and output parameters are given together with the area for which they were developed

Input	Output	Area	Goal	Reference
Rainfall and maximum temperature	Epidemic risk	Kenya	Early warning	Githeko and Ndegwa (2001)
Malaria vector density	Epidemic risk	Uganda	Early warning	Lindblade, Walker and Wilson (2000)
Number of presumptive malaria cases	Epidemic risk	Madagascar	Early warning	Albonico et al. (1999)
Normalized Difference Vegetation Index (NDVI)	Malaria seasonality	Kenya	Predicting malaria transmission seasonality	Hay, Snow and Rogers (1998)
Rainfall and temperature	Distribution of *An. gambiae s.s.* and *An. arabiensis*	Africa	Facilitating species-specific vector-control activities	Lindsay, Parson and Thomas (1998)
Temperature, NDVI, cold-cloud duration and elevation	Distribution of 5 sibling species of the *An. gambiae* complex	Africa	Forecasting malaria	Rogers et al. (2002)
Rainfall and temperature	Distribution of malaria transmission	Africa	Providing basis for predicting impact of climate change	Craig, Snow and Le Sueur (1999)
Rainfall, temperature and population data	Distribution of population exposed	Africa	Providing risk map for malaria mortality	Snow et al. (1999)[1]
Temperature and rainfall	Potential malaria risk	World	Assessing malaria risk in relation to climate change	Martens et al. (1995)

[1] Based on the model of Craig, Snow and Le Sueur (1999)



TEMPERATURE & MALARIA CASES



TEMPERATURE & MALARIA CASES

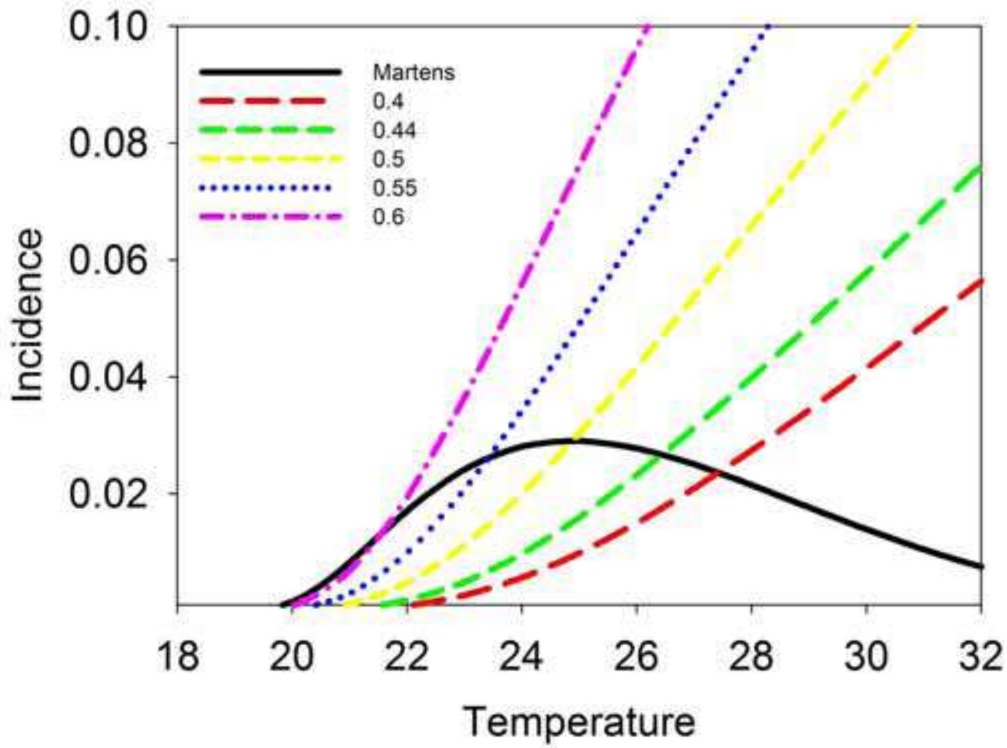
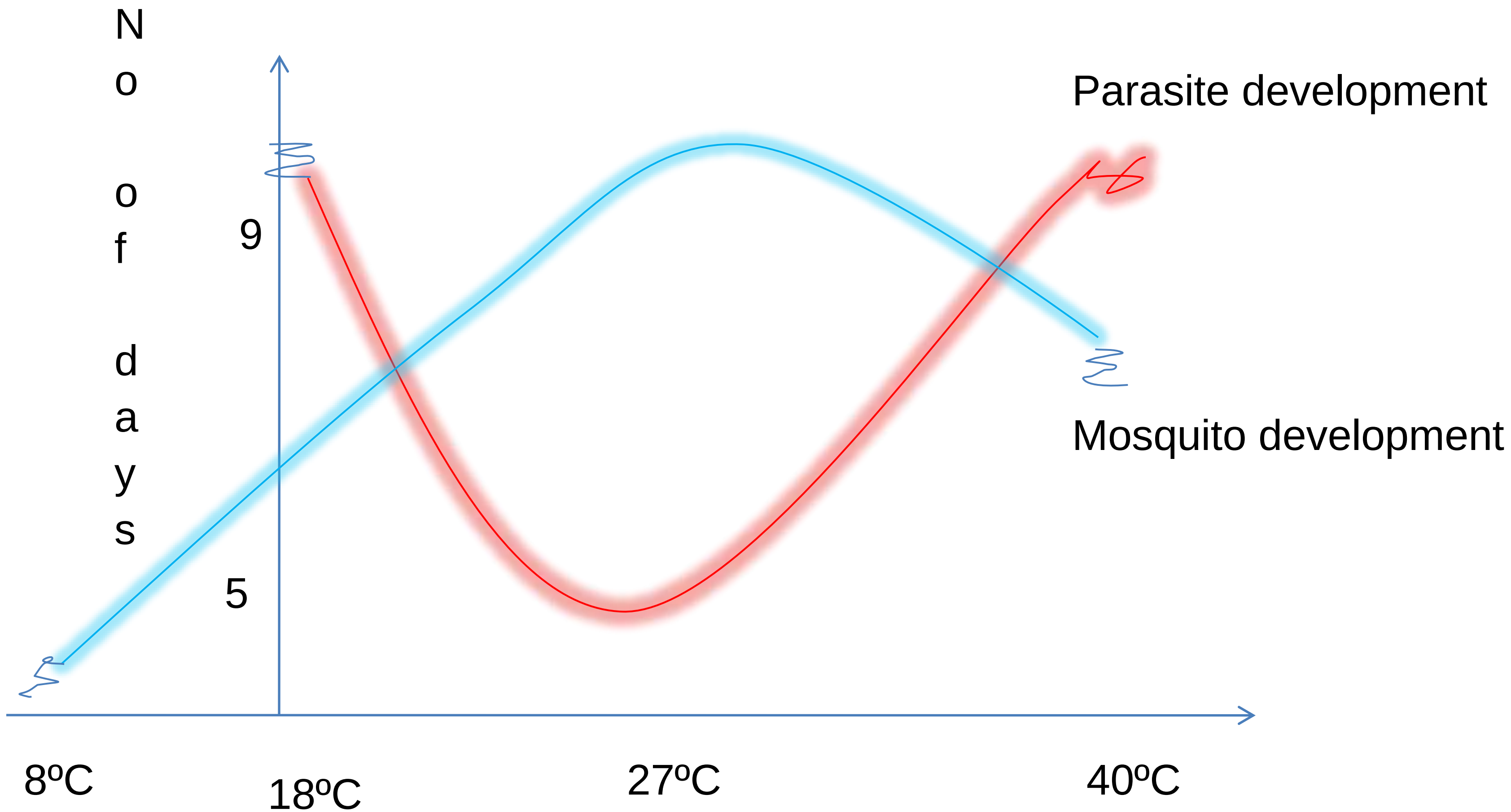


Figure 4. Comparison of Martens and
Birley-Lindsay models of predicted
incidence for
various average temperature values.
Different values of gonotrophic-cycle
survival are
simulated

CLIMATE & MALARIA TEMPERATURE



ENVIRONMENTAL CHANGE AND MALARIA EPIDEMICS: CONTRASTING IMPACTS

↑ Epidemics (WMO, 1999)

Eastern Africa

El Nino

Heavy rainfall, flooding

Tanzania

↓ Cases (Lindsay et al 2000)

I*malaria vs Environmental change*

- Historical Patterns: ↑ in cases / epidemics could not be explained by
  - ↑ in Temp
  - Climate change
  - (shanks et al 2000, 2002; Hay et al 2002)

Studies: Rakotomanana et al 2010. Antananrivo, Madagascar

- Methods
  - GIS for data integration on altitude, temp, rainfall, pop dens & surface area (rice field)
  - Entomological for species determination, breeding sites & infectivity (risk of transmission)
  - Incidence by PCR on dried blood spots & rapid tests for febrile school children
- Results
  - PCR = 5.1%; An arabiensis; rice fields
  - Travel report related to P falciparum

Rakotomanana et al 2010. Antananrivo, Madagascar

- Conclusion: Environmental Factors
  - No direct relationship with incidence
  - Ensuring the suitability of vector development

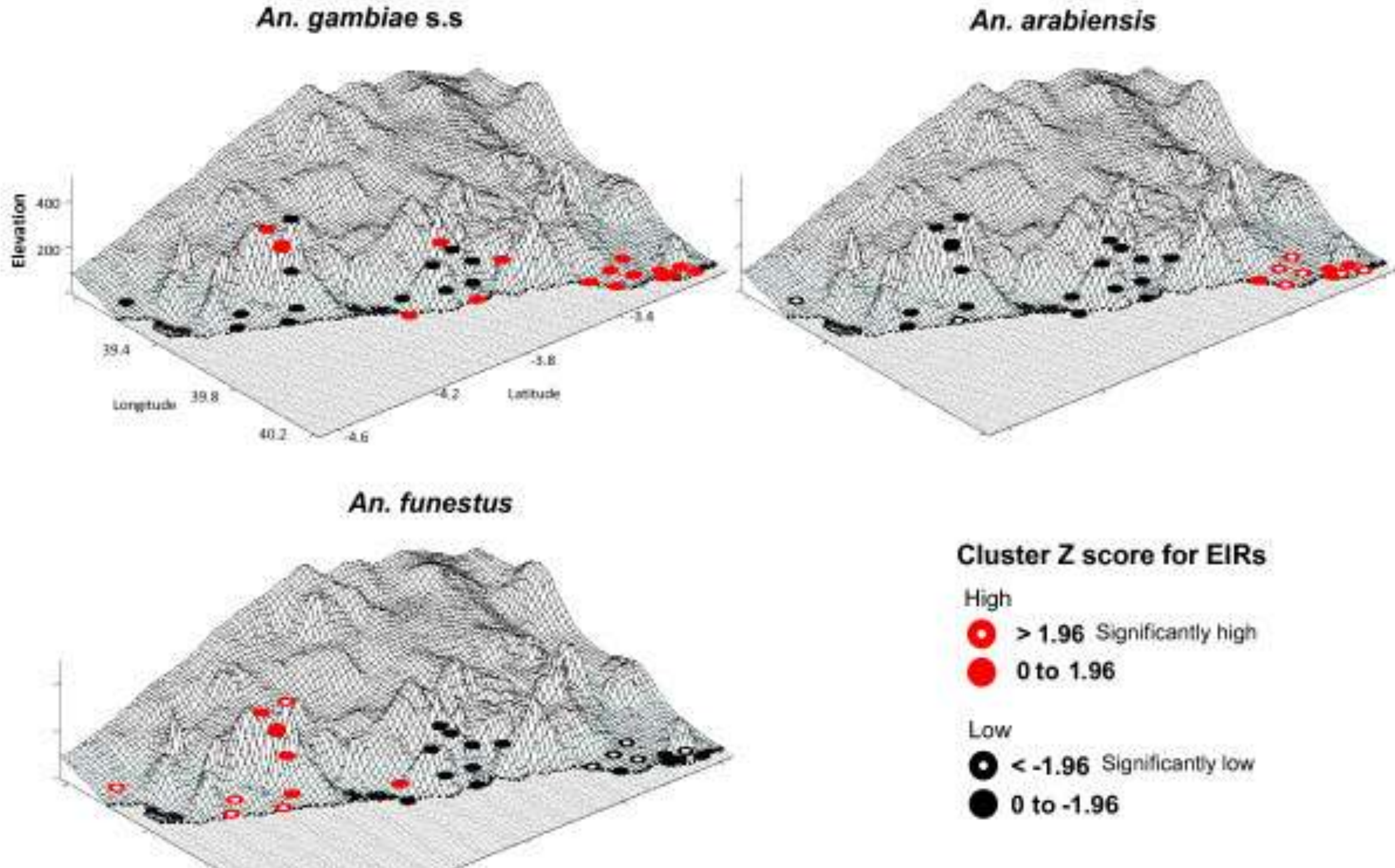
Macro vs Micro-scale
The Need For Peridomestic Analysis

- Macro-scale: global impact assessment
- Micro-scale (Peridomestic):
  - Local assessment
  - Highlight major contribution of environmental features (EF) to malaria incidence (MI)
  - Stefani et al 2011: multivariate peridomestic landscape characterisation that maximises chances of identifying relationships between EF & MI
- Conclusion: environment-based predictive model of MI in neotropical rainforest area

Table 1. Malaria control measures (Nájera et al, 1992)

Action Envisaged	Individual and family protection	Community protection
Reduction of man-mosquito contact	Bednets, repellents, protective clothing, screening of houses	Site selection, zooprophylacsics
Destruction of adult mosquitoes	Use of domestic space spraying (aerosols) space spraying	Residual indoor insecticides, ultra-low volume, sprays
Destruction of mosquito larvae	Peridomestic sanitation, intermittent drying of water containers	Larviciding of water surfaces, intermittent irrigation, sluicing, biological control
Source reduction	Peridomestic sanitation, Small-scale drainage	Environmental sanitation, water Management, drainage
Destruction of malaria parasites	Early diagnosis and treatment, chemo prophylactics	Establishment of diagnosis and treatment facilities, chemo prophylactics for pregnant women, mass treatment
Social participation	Motivation for personal and family protection	Health education, community participation

Hematophagy – the evolutionary brilliance of female mosquitoes to feed on the rich nutrient source of human blood is a critical link in the chain of events leading to the scourge of malaria.



Distribution of spatial clustering trends of high and low EIR values for *An. gambiae* s.s, *An. arabiensis* and *An. funestus*. Note: Z score > 0 indicates a clustering trend of high EIR values (red dots) and Z score < 0 indicates a clustering trend of low EIR values (black dots).

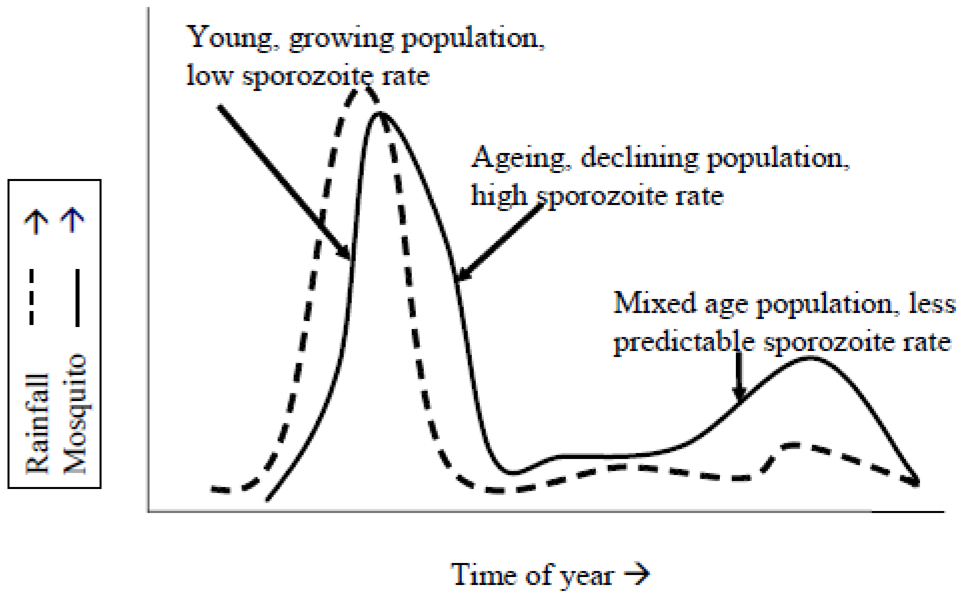
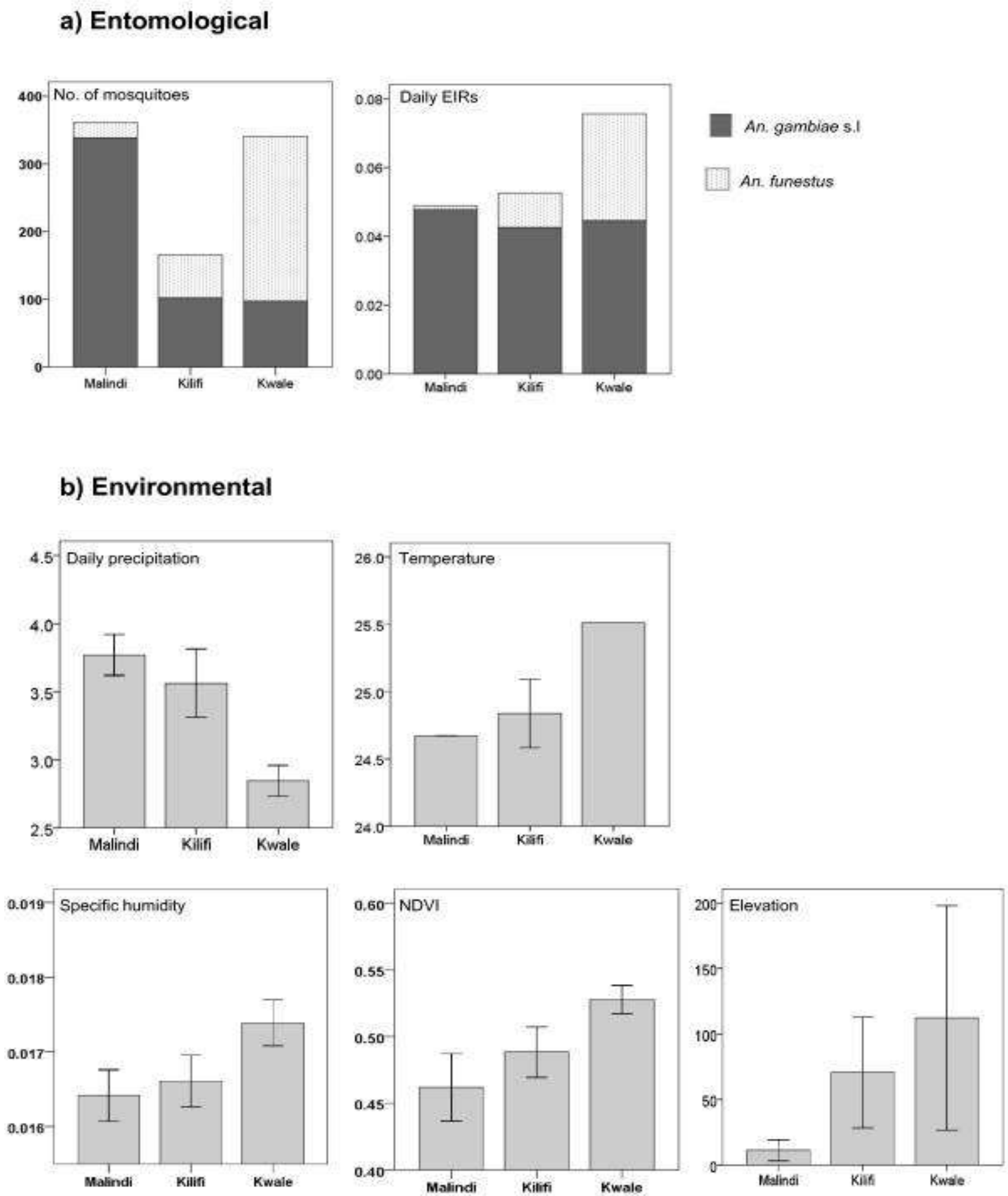
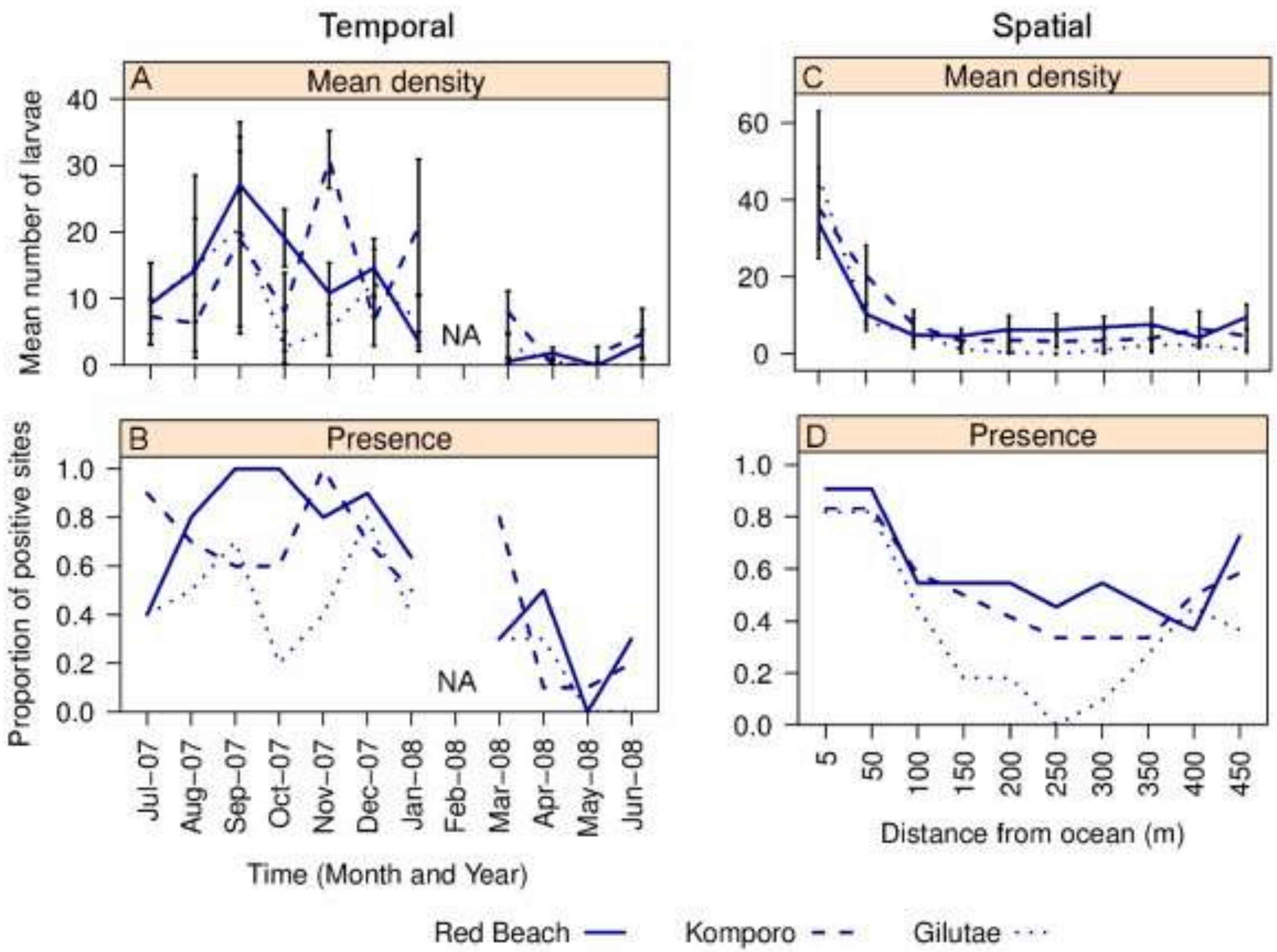


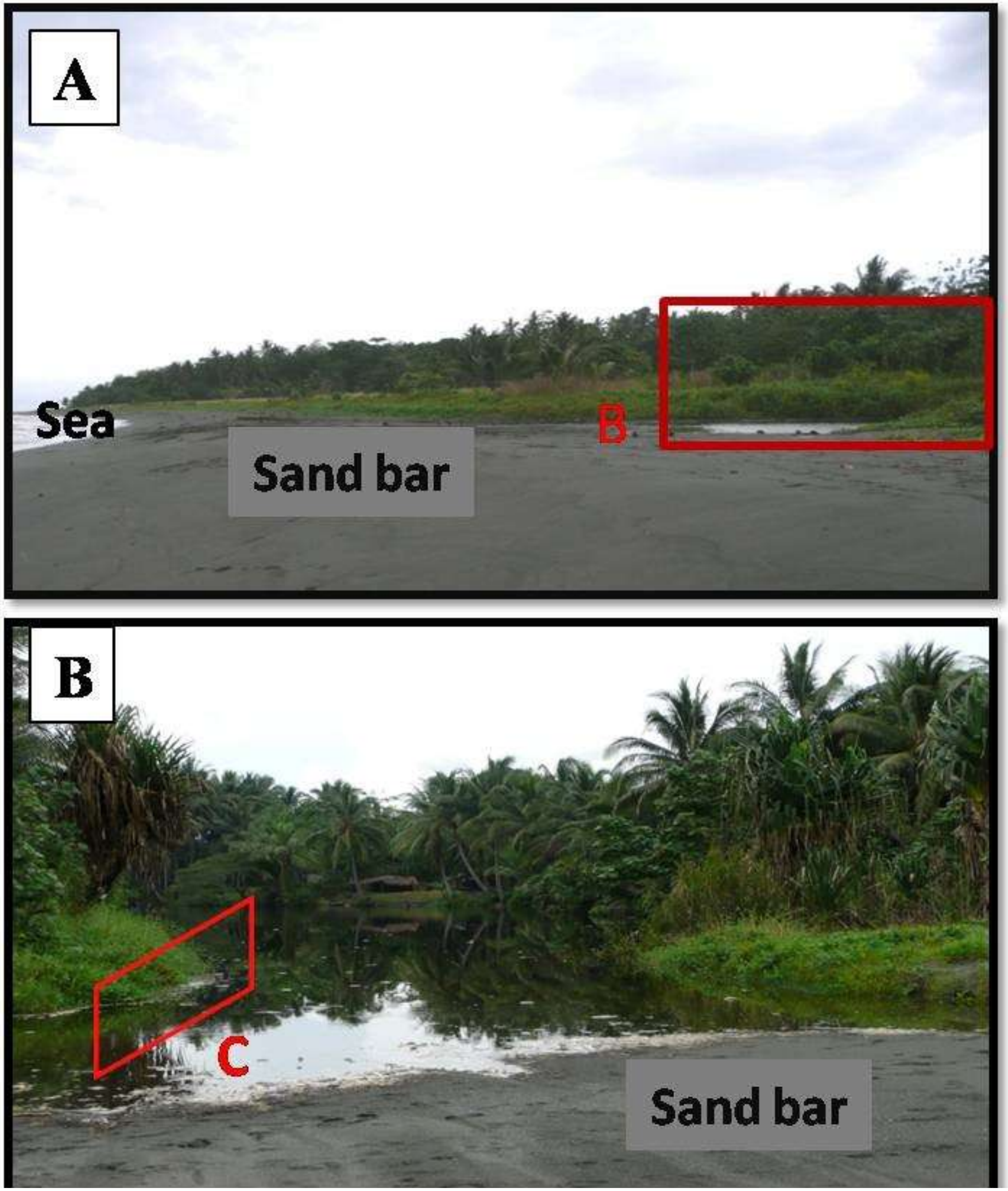
Figure 4. Effects of season on mosquito populations and malaria transmission. Mosquito populations typically lag slightly behind rainfall, such that rainfall increases are often followed by a peak in mosquito numbers (see also Figure 1). Leading up to the peak, mosquito populations are undergoing huge recruitment, will be relatively young and therefore have low salivary-gland infection rates with *Plasmodium* sporozoites. As the population declines, the ageing mosquito population has few if any new recruits and will have an increasingly high sporozoite rate. During periods where the mosquito populations are more stable (short rains for example), the age of the mosquito population can be very mixed and the sporozoite infection rate hard to predict. RA undertaken at any of these times must account for the differences in mosquito population characteristics as well as densities that seasonality will induce



Comparisons of mean entomological and environmental measures by district. Mbogo *et al* 2003.



A temporal and spatial comparison of mean larval mosquito density (A, C; mean ± SE) and the proportion of sites containing *An. farauti* larvae (B, D).
Bugoro *et al. Malaria Journal* 2011 **10**:262



FAVOURABLE ENVIRONMENT

BREEDING PLACES

FAVOURABLE ENVIRONMENT

BREEDING PLACES

Anopheles vs Breeding Sites

- Natural vs man made?
- Why?

Village head Lilin Jumpa says until today, no one has made the effort to consult the villagers on the proposed development, not even the Department for the Development

branches in the process.

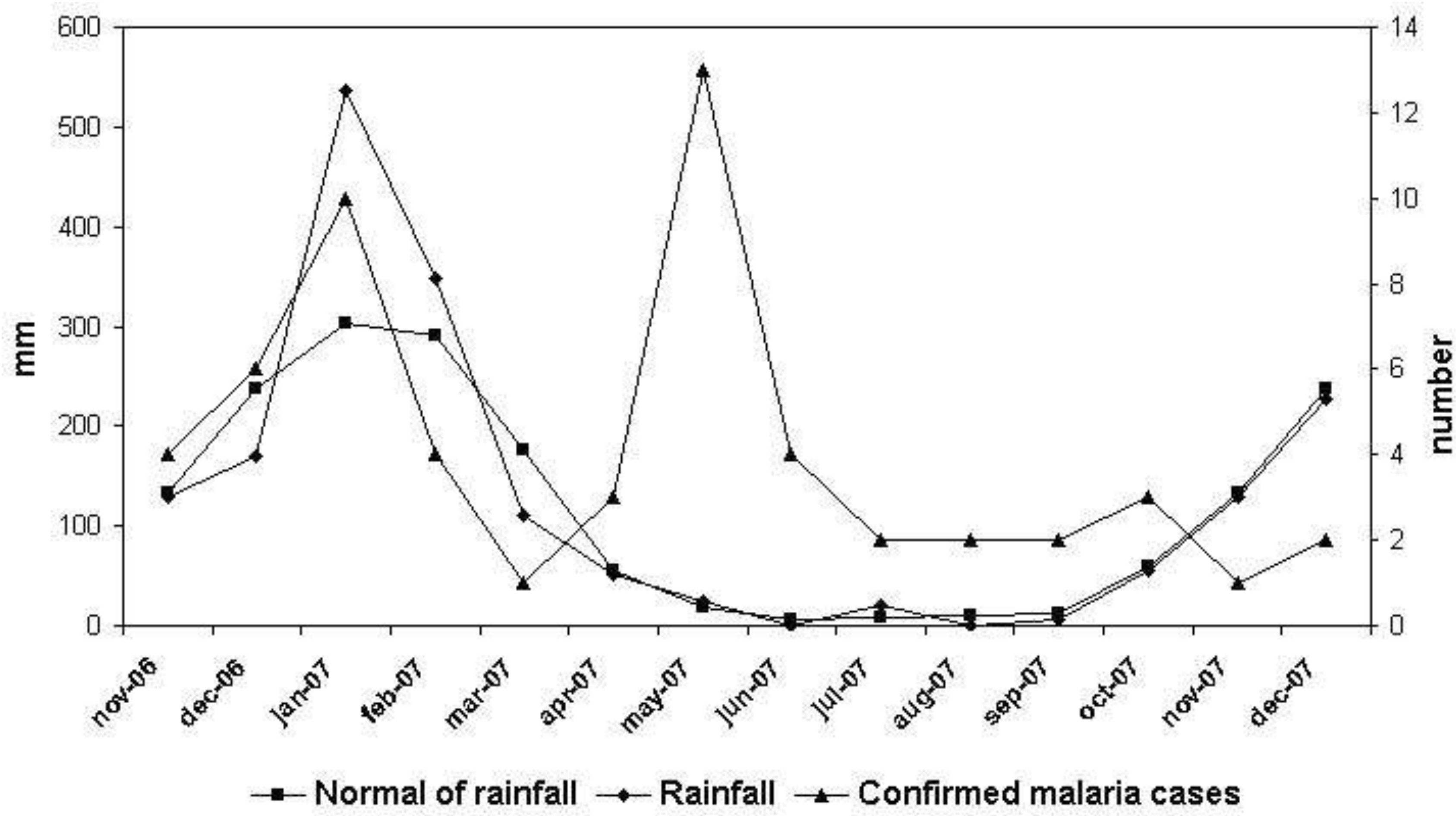
"The village relies on individual tappers to sound the alarm if any elephants are spotted in

The Jakun community of Kampung Punan fears that wild elephants will encroach upon their settlement as more surrounding forest is planted with latex timber clone trees.

The only available patch of forest left in the area will be here (in the village)."

The fact that Kampung Punan is located within the only strip of corridor connecting forest reserves in the north and south

A vital source of water and food for the villagers of Kampung Punan, the Endau River runs alongside land earmarked for yet more rubber plantations.



RAINFALL & MALARIA CASES

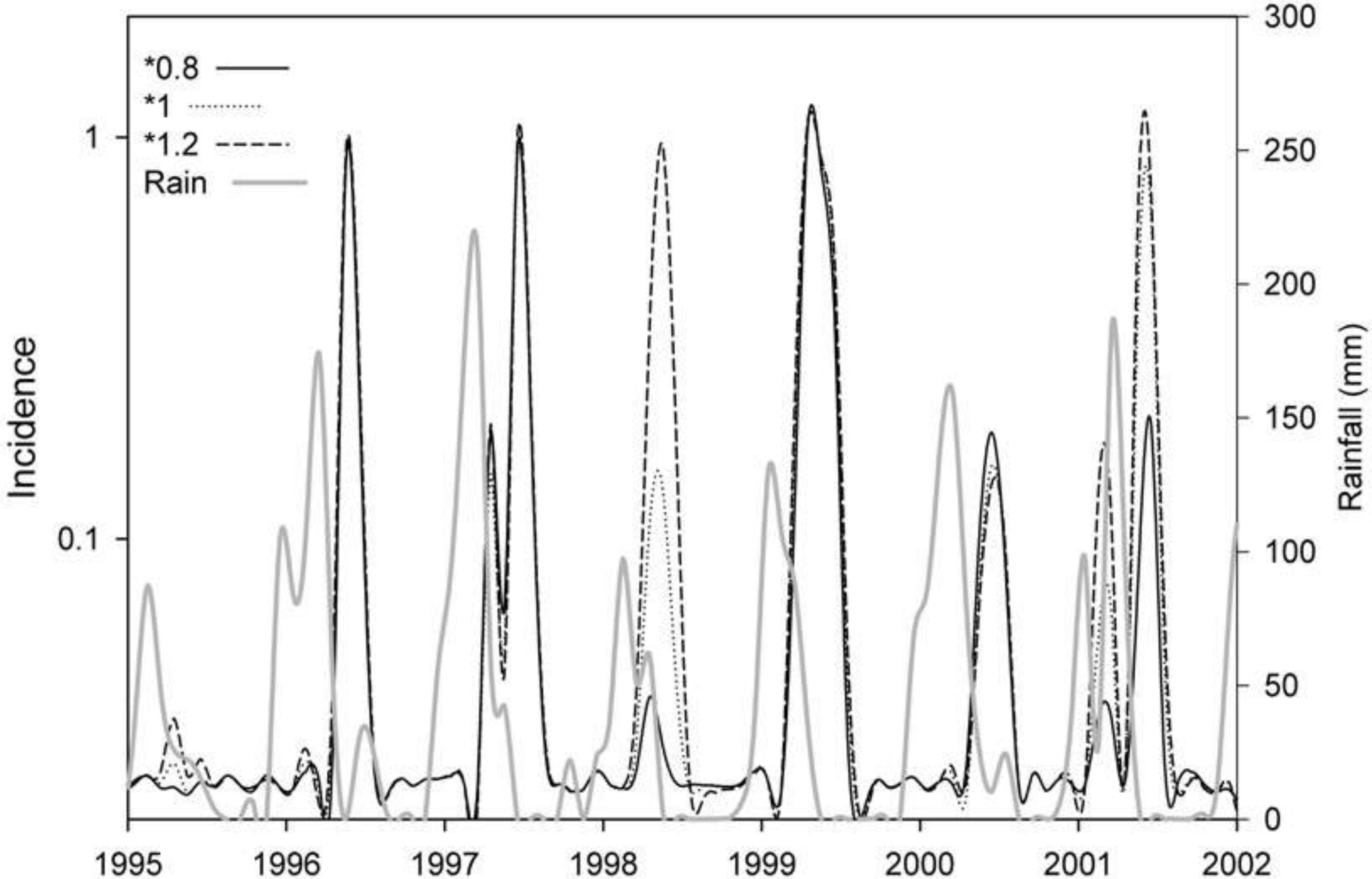
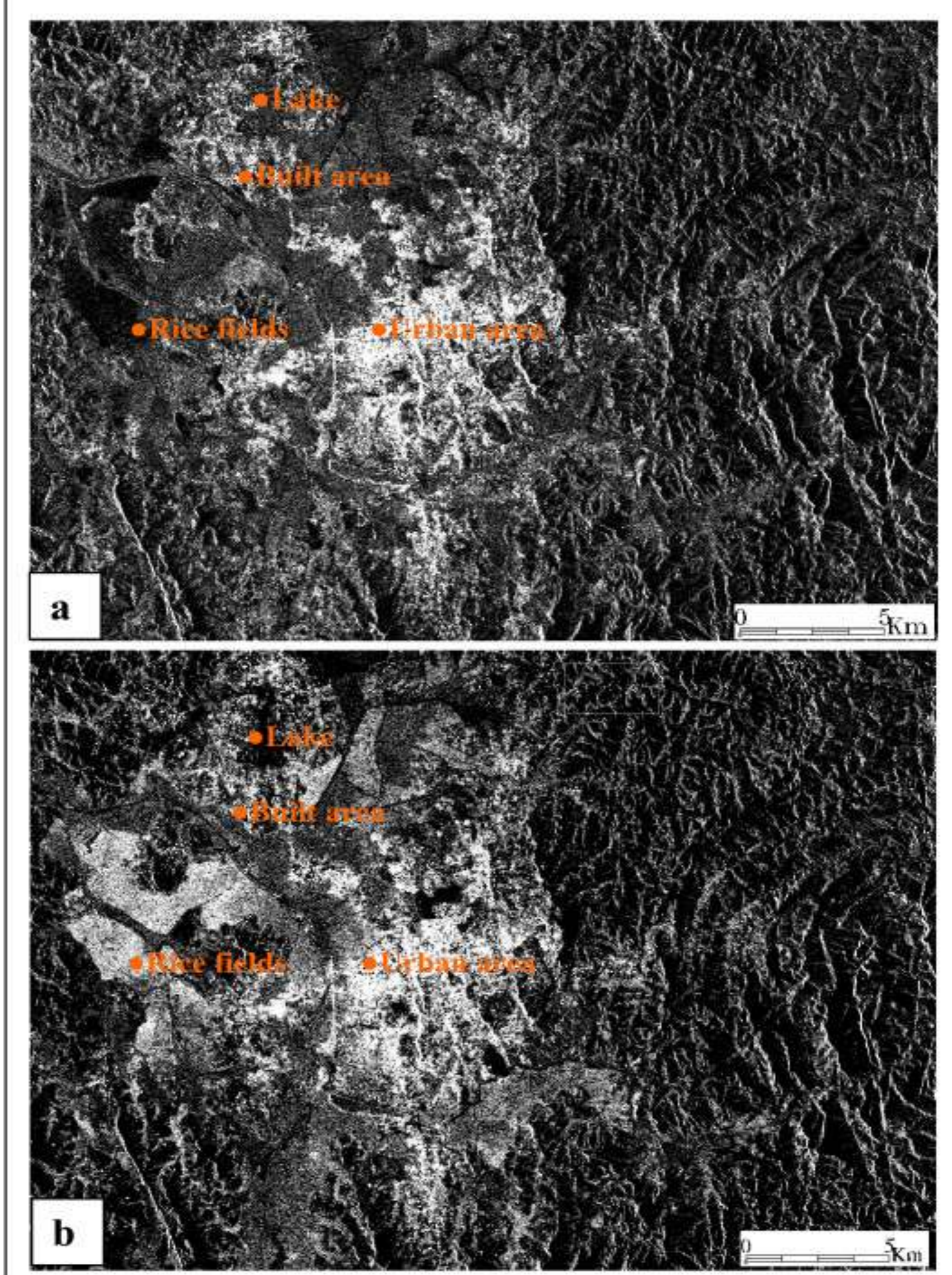


Figure 6. Sensitivity of simulated incidence to variation in rain for 17.5oS 25.0oE using ERA- 40 weather. Calculated rainfall is multiplied by a constant (0.8, 1, 1.2) for the entire simulation



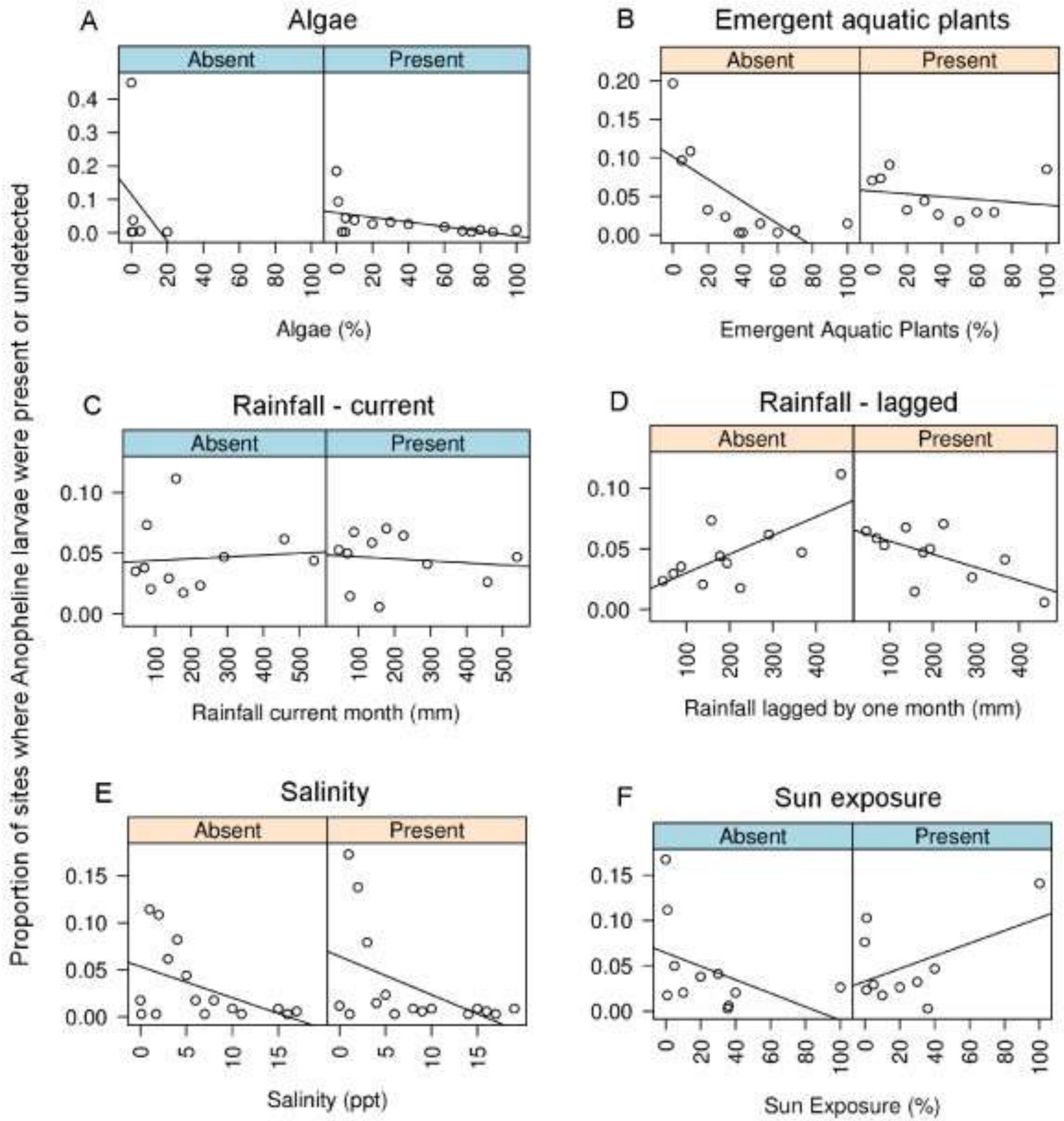
ASAR_IMP_1P images illustrating changes between January and July 2004. Difference between images acquired in January and July 2004.
Rakotomanana *et al. BMC Infectious Diseases* 2010 **10**:173 doi:10.1186/1471-2334-10-173

Table 1

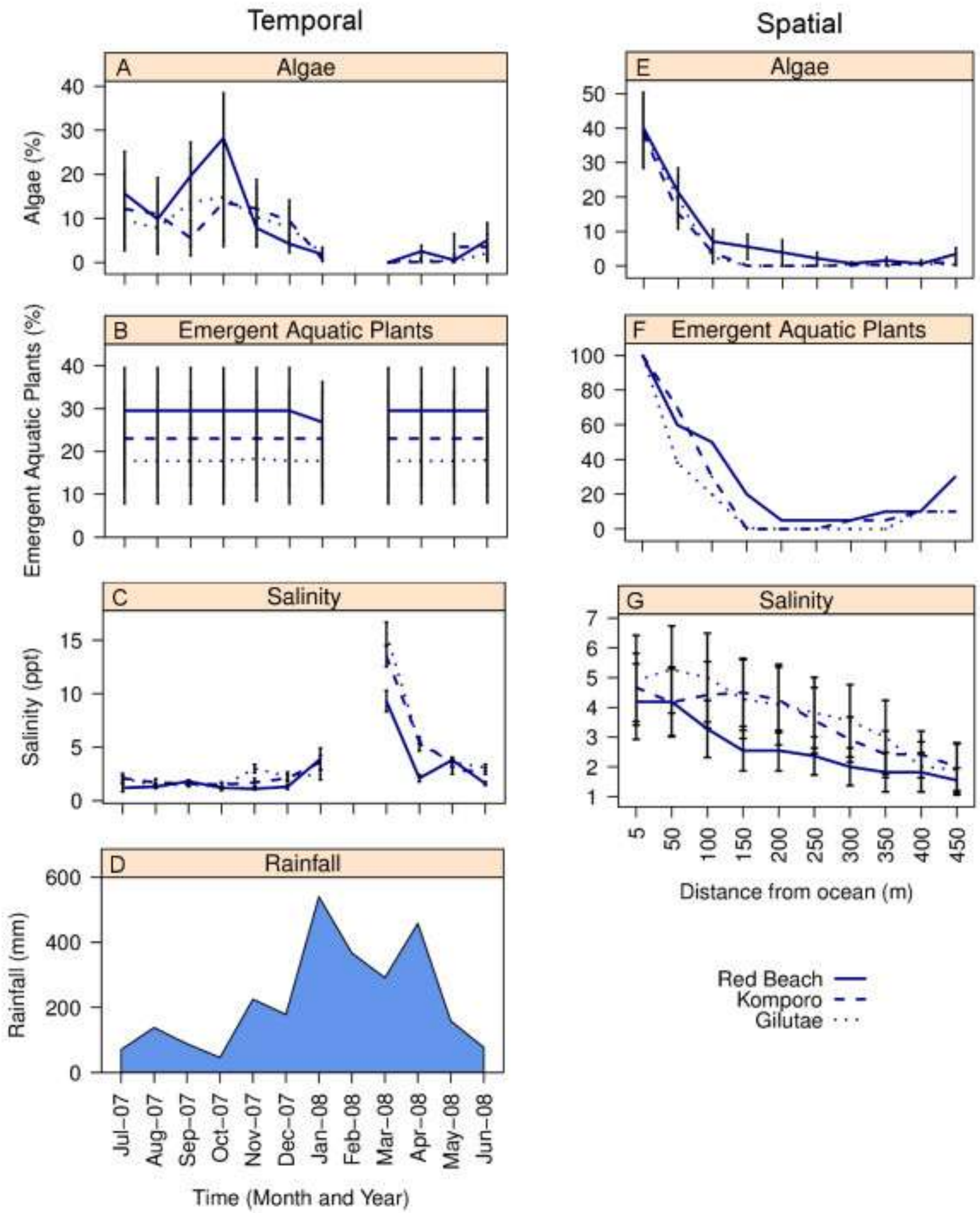
Linear correlations between initial environmental variables and *P. vivax* and *P. falciparum* incidences.

	P. vivax		***P. falciparum#***	
Variable	**Pearson r**	**P value**	**Pearson r**	**P value**
% bare soil#	-0.17	0.381	**-0.69**	< 0.001**
% secondary forest	0,00	0.999	-0.03	0.891
% primary forest	0.08	0.688	**0.54**	0.003**
% deep water	0.28	0.149	**-0.39**	0.043*
% burned land#	-0.24	0.218	**-0.43**	0.022*
% low vegetation	-0.09	0.665	0.06	0.761
% medium vegetation#	-0.05	0.783	0.24	0.227
% high vegetation	0.17	0.396	**0.68**	< 0.001**
% river banks/shallow water#	0.30	0.124	-0.24	0.212
No. of inhabited dwellings#	-0.30	0.116	**-0.60**	0.001**
Length of river banks#	0.32	0.097	**-0.44**	0.018*
Length of creeks#	-0.06	0.771	**0.48**	0.01*
Landscape divison 1	**0.46**	0.013*	-0.10	0.601
Landscape divison 2	**0.49**	0.008**	**0.48**	0.009**

buffers radii = 100 m and 400 m for *P. vivax* and *P. falciparum* incidences, respectively.



Correlations between larval *An. farauti* presence and the 6 environmental factors in the study streams: filamentous algae, emergent aquatic plants, current rainfall, rainfall lagged by one month, salinity and sun exposure. The factors with a pink top-panel were significantly associated with *An. farauti* presence Bugoro *et al. Malaria Journal* 2011 **10**:262



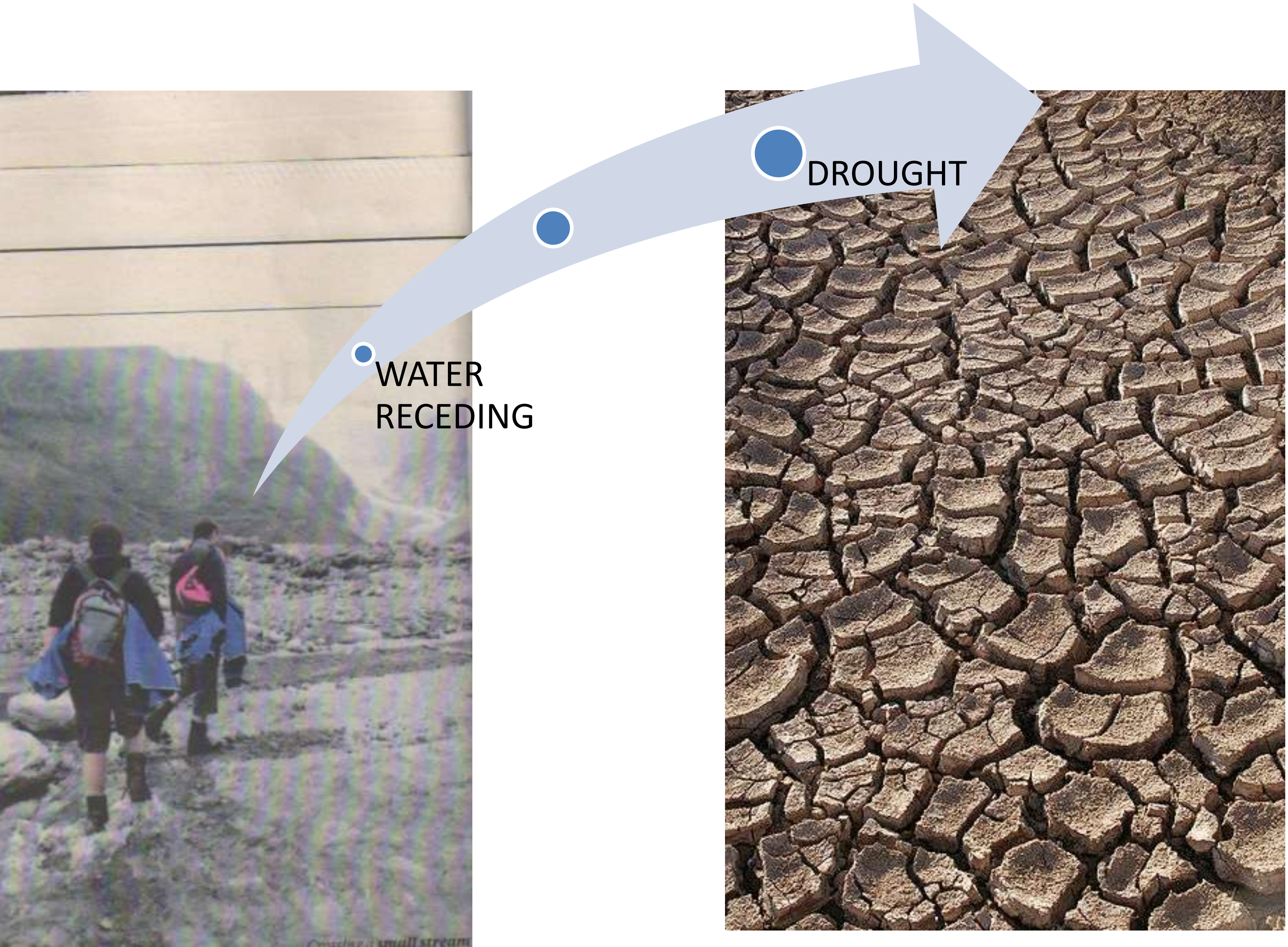
A temporal and spatial comparison of the environmental factors recorded the study streams: filamentous algae (A, E; mean ± SE), emergent aquatic plants (B, F; mean ± SE), salinity (C, G; mean ± SE) and rainfall (D; monthly total). Bugoro *et al. Malaria Journal* 2011 **10**:262

flood

FLOOD

October 12, 2005

September 19, 2005


WATER
RECEDING
DROUGHT

TSUNAMI

GLOBAL
PHENOMENA
LOCAL
IMPACT

December 29, 2004


January 10, 2003

after

Tsunami Destruction of Aceh Province in Sumatra

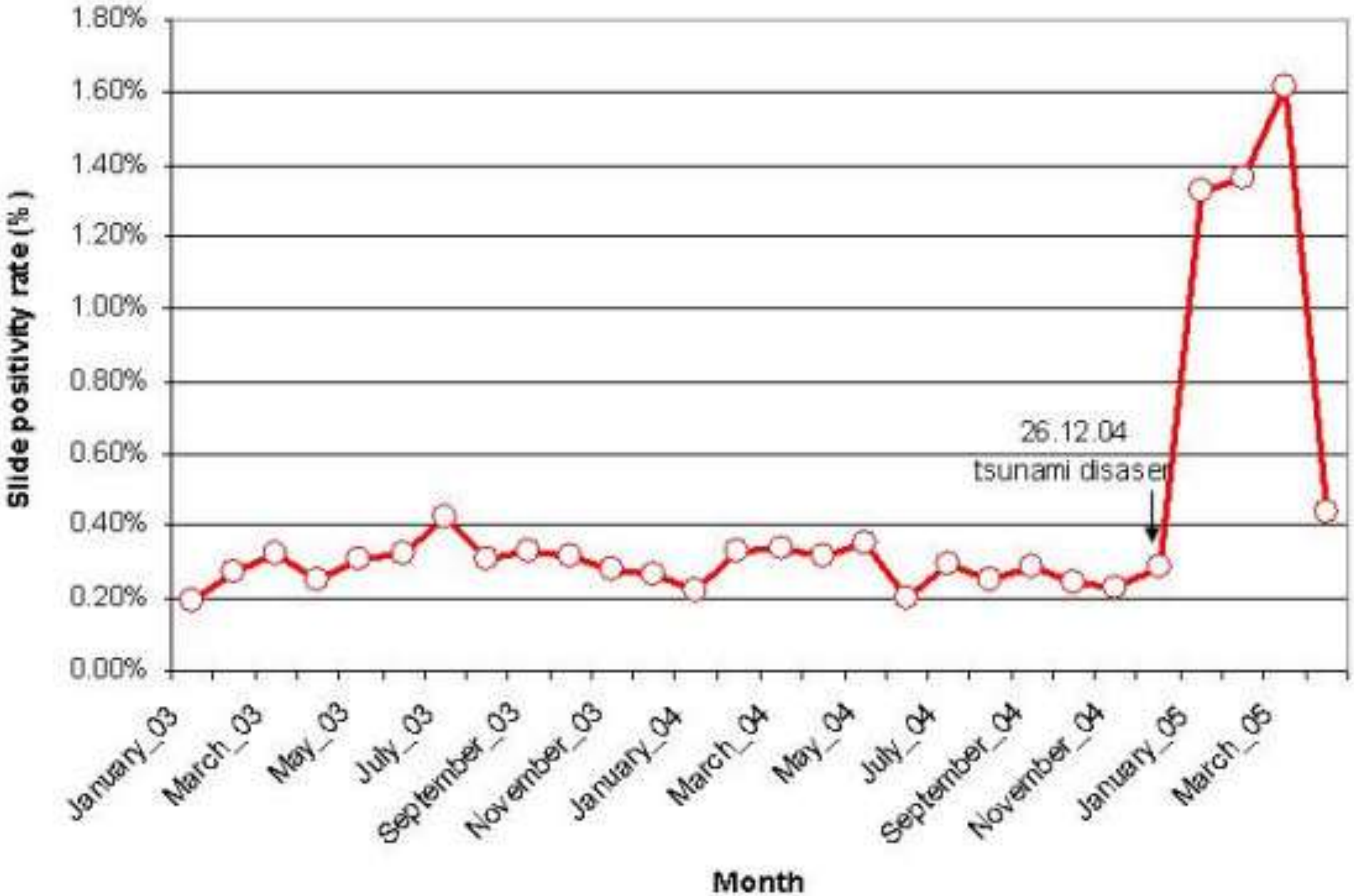
before

Changing Environment
Post Tsunami

POST – TSUNAMI

? IMPACT ON MALARIA

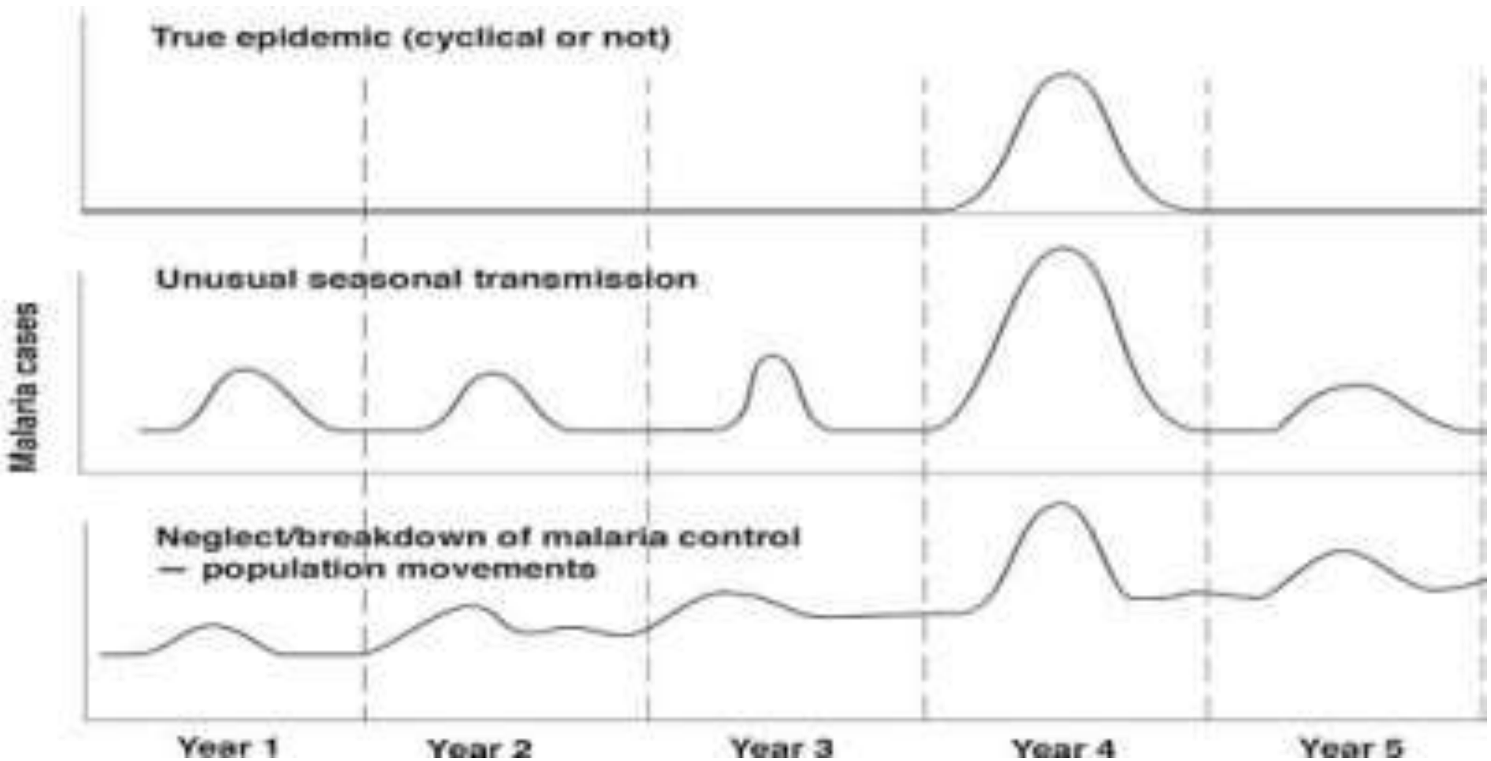
Tsunami and *Imalaria*



Environmental Change
Local Variations

- Geographical characteristics
  - Highland
  - Valley
- Land cover / Land Use
  - Bare highland
  - Marshes / Bushes
  - Agriculture
- Infrastructure / Township

Malaysia: New Epidemics

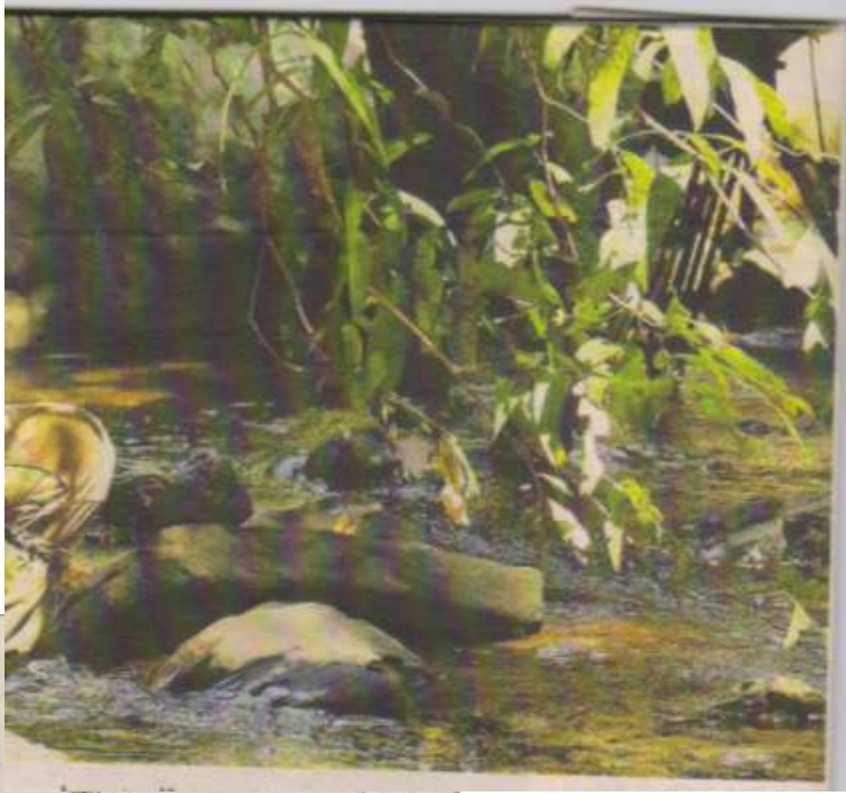


Top: A 'true' epidemic, i.e. an infrequent event occurring in areas where the disease does not normally occur. This type of epidemic is often associated with warm dry regions. This type of epidemic may be cyclical in nature.

Middle: An unusually high peak in transmission in areas where malaria is normally seasonal. This type of epidemic often happens in the highland fringes. These epidemics may also be cyclical in nature.

Bottom: A 'resurgent outbreak' where neglect or breakdown in control allows malaria to try to return to its higher 'pre-control' level. May be associated with more complex emergency situations involving political instability and displaced populations. [14]

Ecology & Landscape



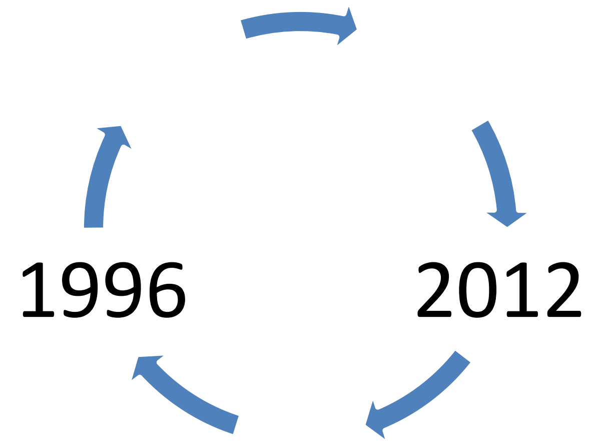
A large portion of the area designated for latex timber clone plantations in Johor consists of freshwater swamps which logically, should be preserved as they act as water storage facilities.

Heavenly peace

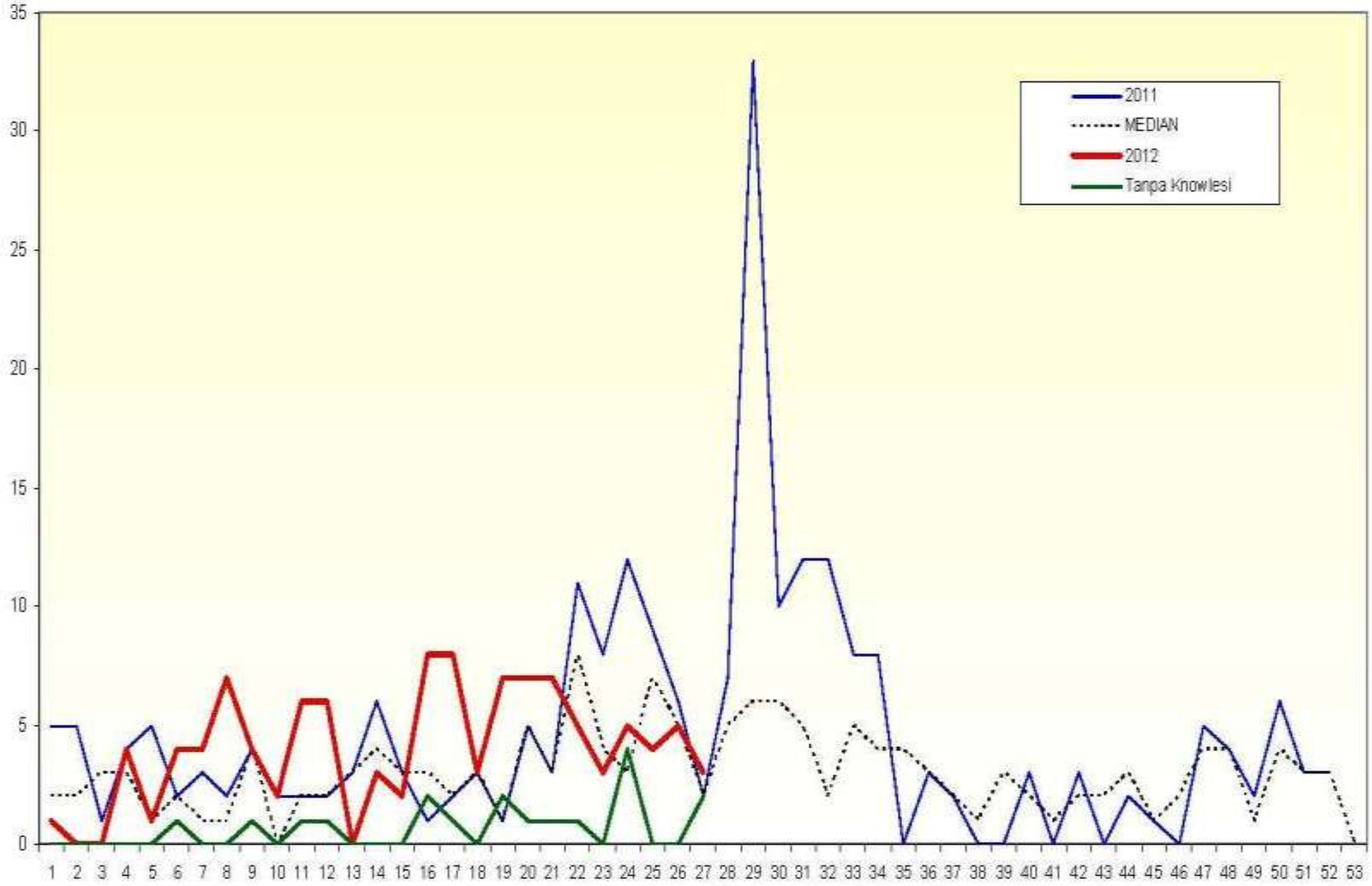
Electric fencing and deep ditches, built to keep elephants away from rubber tree estates, can instead, impede wildlife migration and fragment important habitat.

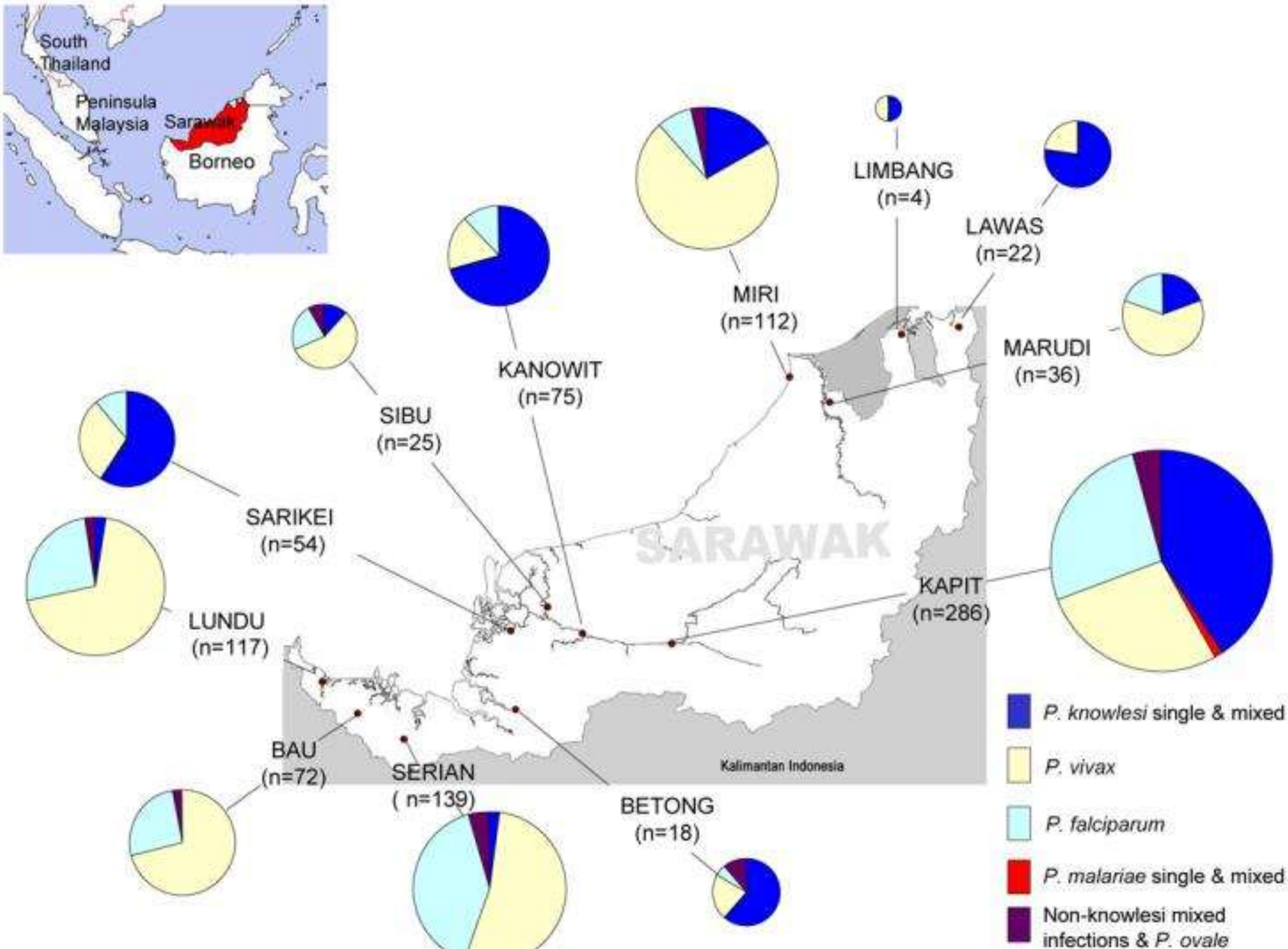
Ecology & Landscape

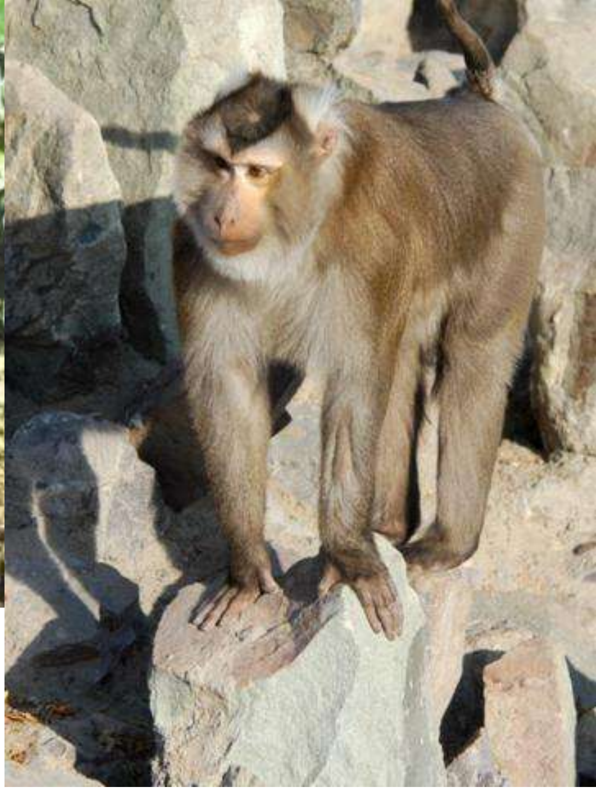
Ecology & Landscape



Rajah 5 : Perbandingan Notifikasi Kes Malaria Tahun 2011, Median 2007-2011dan 2012




South
Thailand
Peninsula
Malaysia
Sarawak
Borneo
LIMBANG
(n=4)
MIRI
(n=112)
LAWAS
(n=22)
KANOWIT
(n=75)
MARUDI
(n=36)
SIBU
(n=25)
SARIKEI
(n=54)
SARAWAK
KAPIT
(n=286)
LUNDU
(n=117)
BAU
(n=72)
SERIAN
(n=139)
BETONG
(n=18)
Kalimantan Indonesia
P. knowlesi single & mixed
P. vivax
P. falciparum
P. malariae single & mixed
Non-knowlesi mixed
infections & P. ovale




WALTER REED
BIOSYSTEMATICS UNIT

Plasmodium knowlesi

- Potentially life threatening
- Misdiagnosed as P malariae until recently
  - Distinguished by nested PCR assays

- Short 24-hour asexual life cycle

↓

high parasitaemia

↓

prompt treatment

KNOWLESI MALARIA

NEW OR UNRECOGNISED THREAT?

Thin & thick films of a real patient