Malaria vectors and pattern of malaria transmission in East Central India: from control to elimination

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Intrinsic and extrinsic factors of malaria transmission

Parasite / virus (infected persons)

Control and preventive measures

Social, Behavioural, Economic and Political factors

Vector

Human

Environmental conditions

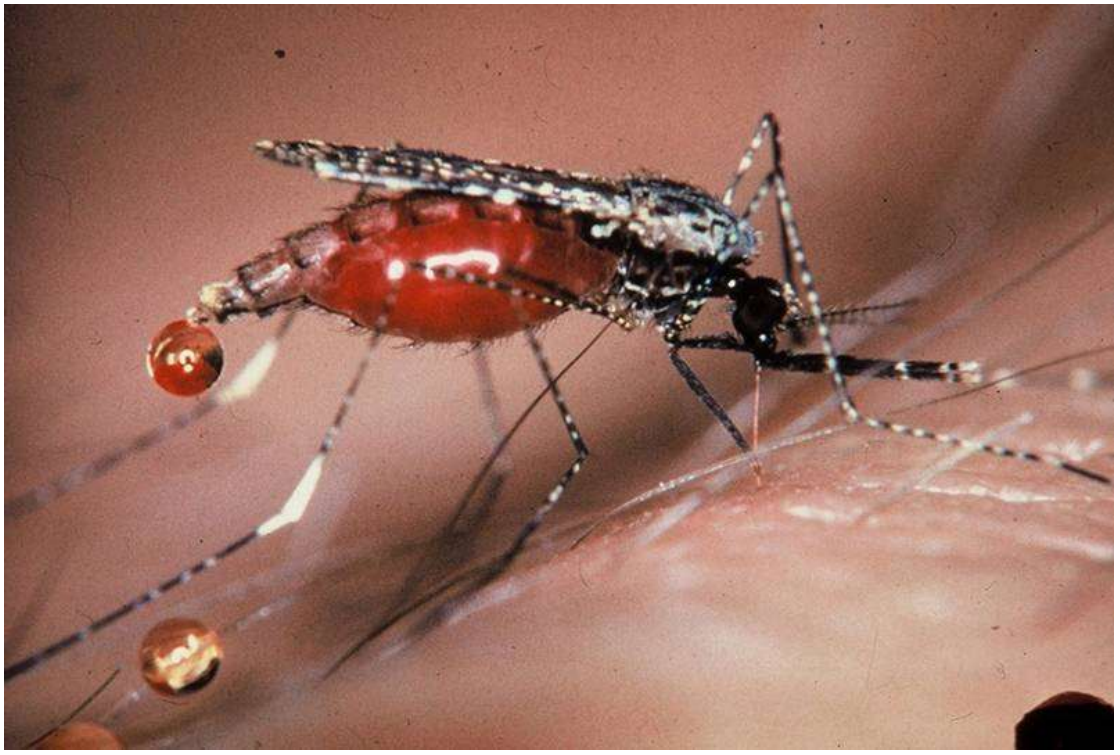
Vector

Factors that influence a vector's capacity to transmit a disease or vector's transmission efficiency.

- the vector species must be susceptible to the parasite species and be able to maintain or excrete the pathogen.
- its longevity must be sufficient to allow the developmental cycle to be completed
- it must exist in sufficient density
- it must bite the target host frequently

it must have some means of mobility
the vector must be adaptable to the changing environment

Anopheles dirus; note white “knees” on hind legs; major malaria vector in forests of South East Asia



Malaria vector life cycle and behaviour

Blood-meal on animal

Blood-meal on humans

Rest outdoors

Rest indoors

Egg laying

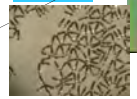
Fertilized female

Emerging male

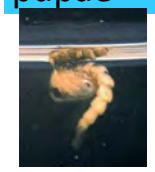
Emerging female

AIR

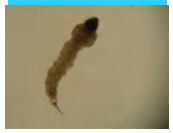
eggs



pupae



larvae



WATER

Malaria vector life cycle and behaviour

Zoopro-phylaxis Animal sprays

Personal Protection (ITN, LLIN)

Space spray

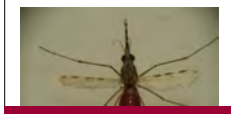
Blood-meal on animal

Blood-meal on humans

Fertilized female

Rest outdoors

Rest indoors



Indoor residual spray

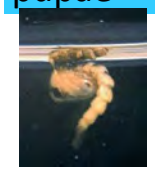
Egg laying

Emerging male

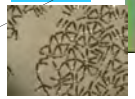
Emerging female

AIR

pupae

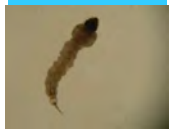


eggs



Ovicide traps

larvae



WATER

Larval control: Chemical, Mechanical & Bio-larvicides, Larvivorous fish, Environmental management

The vector's life cycle and behaviour

it assumes gonotrophic concordance (one oviposition per blood meal throughout), whereas in reality the first oviposition often requires two blood meals

it ignores split blood meals, including those split between man and animal

it ignores movement between indoors and outdoors resting within the same gonotrophic cycle

Factors affecting vector production

Rainfall, type of soil, slope of the land, irrigation systems, urbanisation, pollution, forestation and deforestation, existence of borrow-pits, and presence or absence of shade. Many of these factors affect the type of surface water that will be available.

Factors affecting vector survival

Use of insecticides in agriculture, presence of predators and sudden changes in climatic conditions.

Factors that affect human-vector contact

Location of settlements, housing construction, activity patterns of the vector and humans, sleeping habits and the availability of alternative host.

The Vectorial Capacity Model (Garret-Jones 1964)

Factors composing the Vectorial Capacity (C) Model

$$C = \frac{ma^2p^n}{-\log_e p}$$

where,

ma = man biting rate (number of bites per host per night)
a = man biting habit (human blood index times feeding frequency)
p = daily survival probability of the vector
n = the duration of parasite development in the vector
$1/ -\log_e p$ = expectation of life of female vectors

Anti-malaria activities having relationship to the parameters in the R_o equation

Imagociding affects '*p*'

Bednets, screens and repellents reduce '*a*'

larviciding & emerging of landscape reduce '*m*'

Medical treatment affects '*r*'

Chemo prophylaxis affects '*b*'

Malaria vectors in India

(Rao, 1984)

1. *An. culicifacies*
2. *An. fluviatilis*
3. *An. minimus*
4. *An. stephensi*
5. *An. philippinensis*
6. *An. balabacensis*
7. *An. annularis*
8. *An. sundaicus*

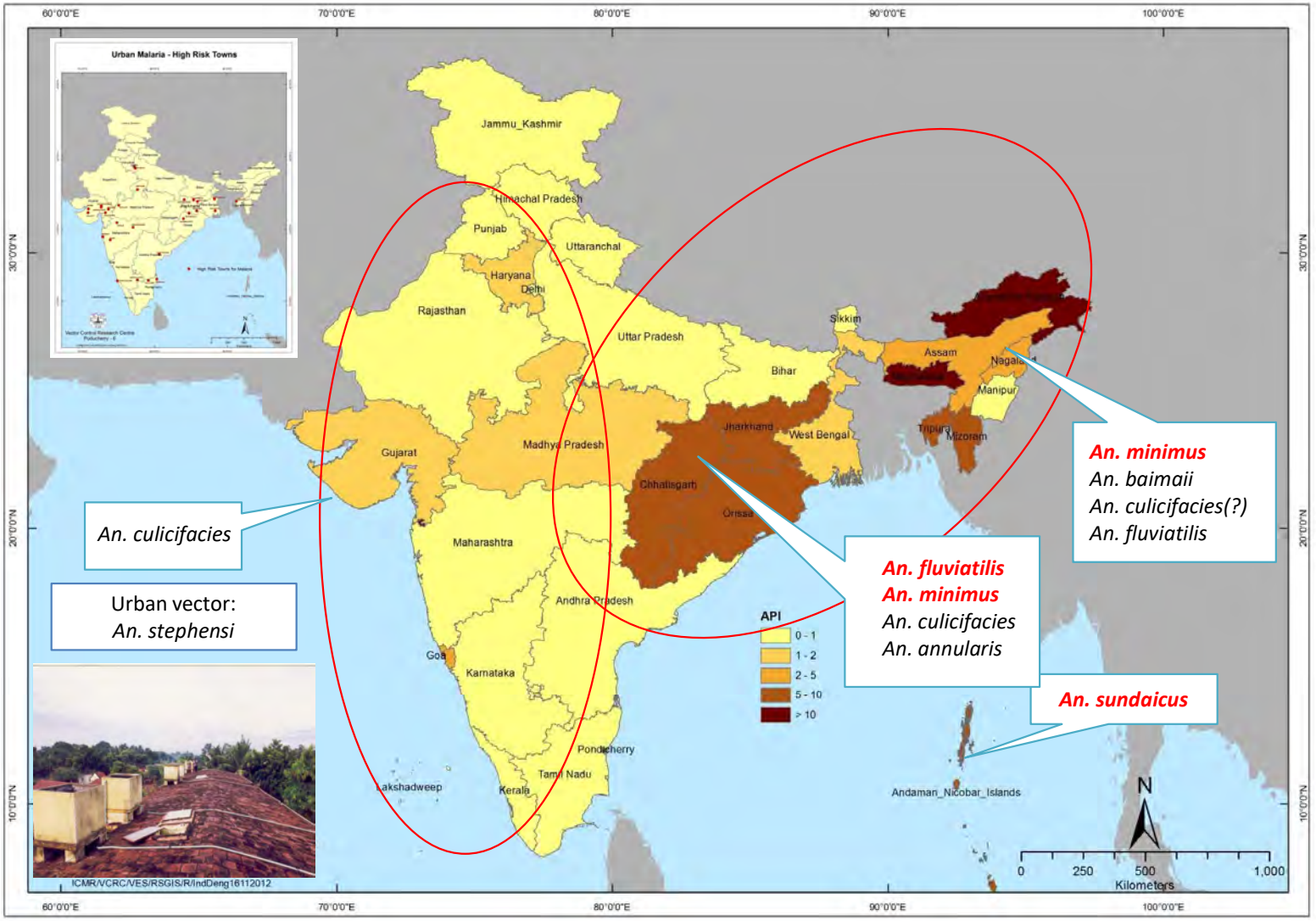
1. *An. varuna*
2. *An. aconitus*
3. *An. jeyporiensis var. candidiensis*
4. *An. maculatus*
5. *An. tessellatus*
6. *An. subpictus*

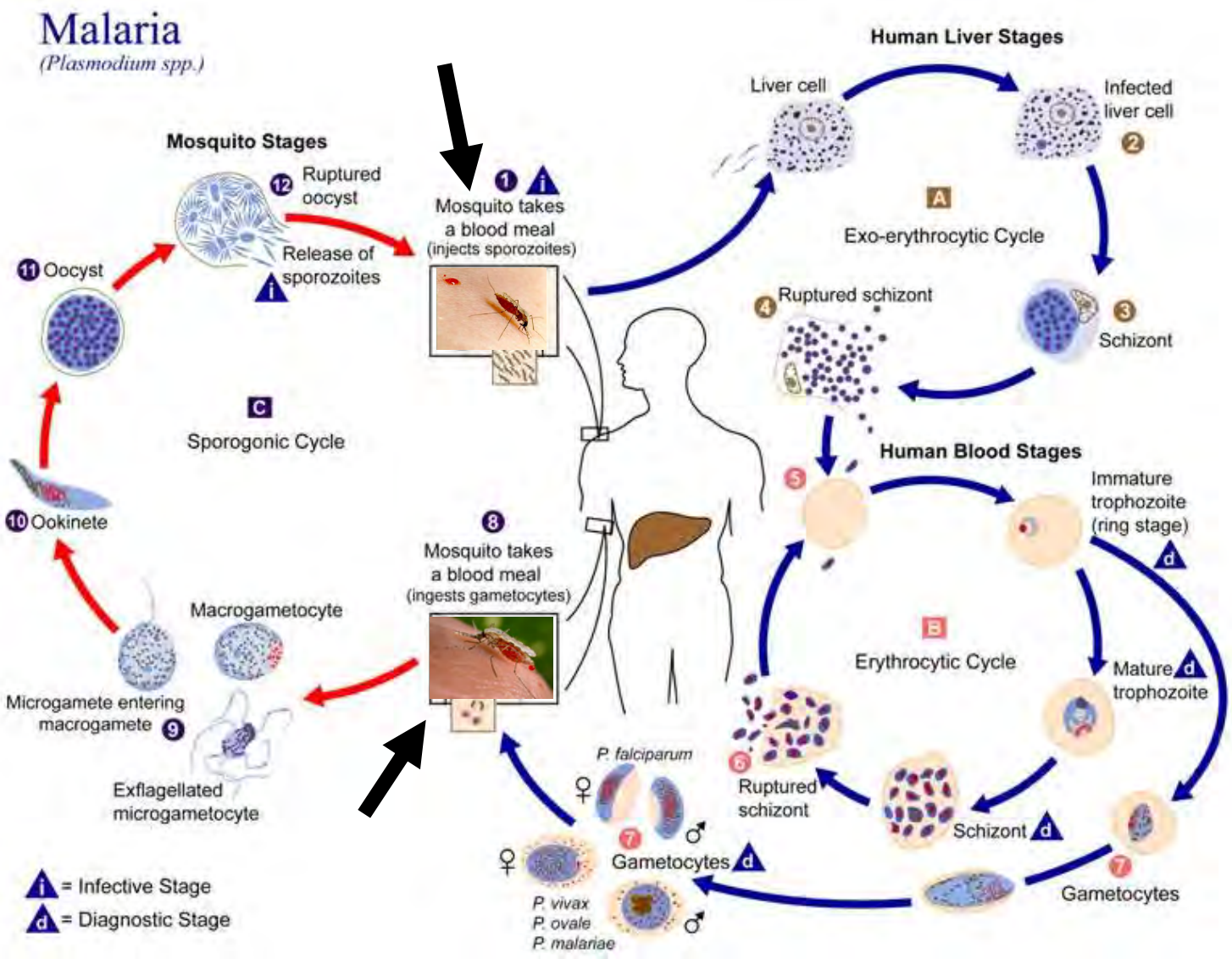
(Current)

1. *An. culicifacies*
2. *An. fluviatilis*
3. *An. minimus*
4. *An. stephensi (urban)*
5. *An. baimaii*
6. *An. sundaicus*

1. *An. annularis*
2. *An. philipinensis*

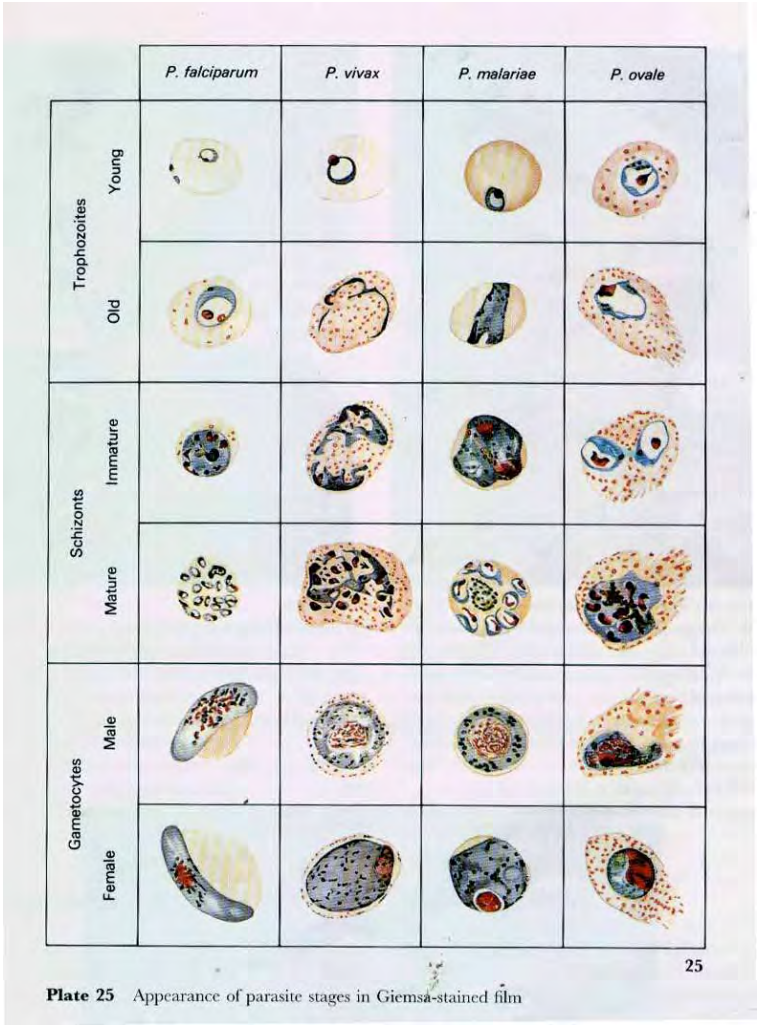
Distribution of malaria (2008-2012) and its vectors in India



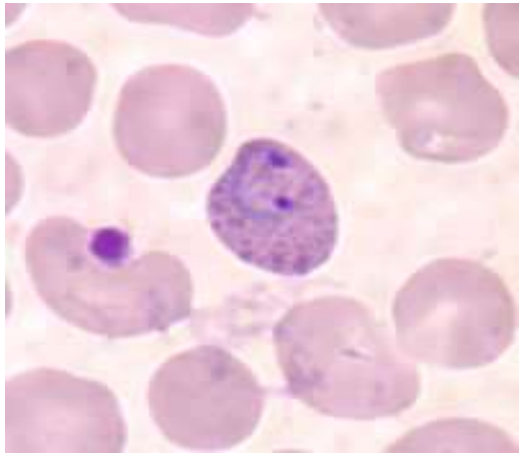
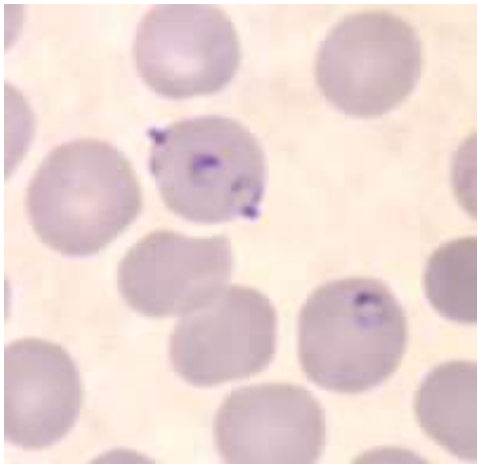
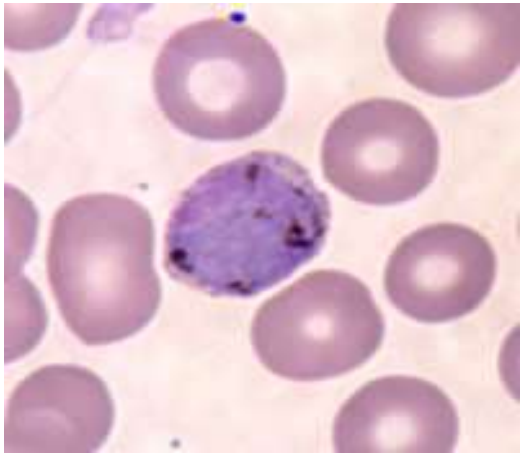
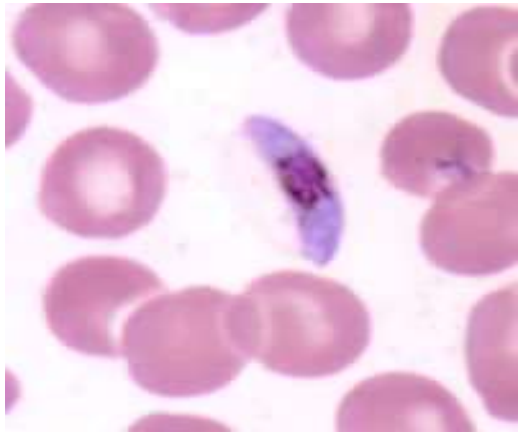

Malaria
(Plasmodium spp.)
Human Liver Stages
Liver cell
Infected liver cell
2
A
Exo-erythrocytic Cycle
4 Ruptured schizont
3 Schizont
Human Blood Stages
5
Immature trophozoite (ring stage)
d
B
Erythrocytic Cycle
Mature trophozoite
6 Ruptured schizont
Schizont
d
7 Gametocytes
d
P. falciparum
P. vivax
P. ovale
P. malariae
Gametocytes
Mosquito Stages
12 Ruptured oocyst
Release of sporozoites
i
11 Oocyst
C
Sporogonic Cycle
10 Ookinete
1 i
Mosquito takes a blood meal
(injects sporozoites)
8
Mosquito takes a blood meal
(ingests gametocytes)
Macrogametocyte
Microgamete entering macrogamete 9
Exflagellated microgametocyte
i = Infective Stage
d = Diagnostic Stage

Four species of human malaria parasites

- ***Plasmodium vivax*** (Grassi and Feletti, 1890)
- ***P. falciparum*** (Welch, 1897)
- *P. malaria* (Laveran, 1881)
- *P. ovale* (Stephens, 1922)



Different stages of human malaria parasites

	P. vivax	*P. falciparum*
Ring forms		
Gametocytes		

Socio-economically weaker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- Epidemiological characteristics, transmission dynamics, magnitude of the malaria problem depend on the place and time I.e local conditions: climate and environment

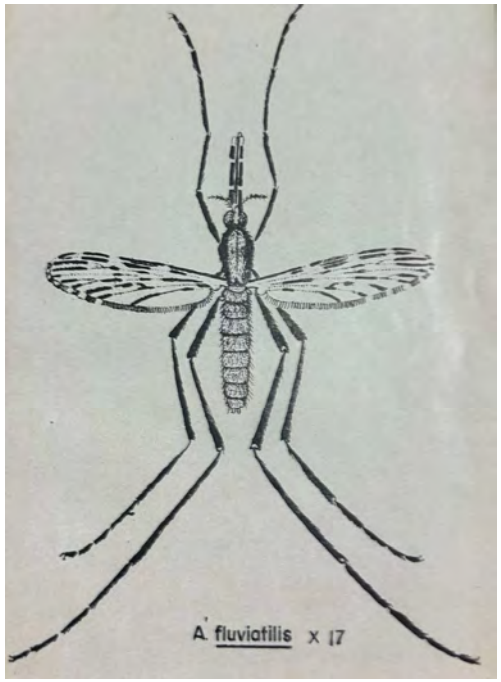
"Everything about malaria is so moulded by local conditions that it becomes a thousand epidemiological puzzles. Like chess, it is played with a few pieces but is capable of an infinite variety of situations."

- L.W. Hackett (1937)

Malaria in East Central India (e.g. Odisha) in the context of elimination

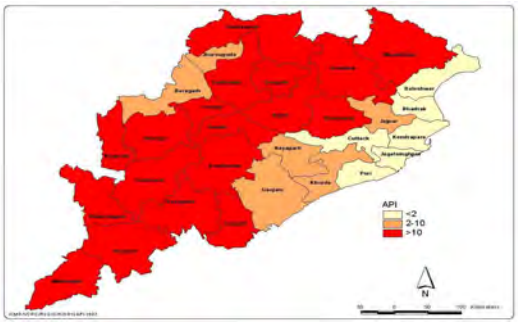
- For many decades, this region has been highly endemic (hyper endemic) for malaria
- Predominantly *P. falciparum* infections (>90%), malaria deaths mostly among children. *P. vivax* and *P. malariae* were also recorded.
- Intense and perennial transmission (throughout all seasons)
- High incidence among infant and children, immune and semi-immune population
- Based on response to the control measures, this was classified as areas of **Inaccessible malaria.**

- Multiple vectors
- Efficient vectors with high vectorial capacity
- *An.minimus,* an indoor resting mosquito disappeared from major part of the hill tract due to deforestation and insecticide pressure.
- *Anopheles fluviatilis & Anopheles culicifacies*
- *An. fluviatilis* - predominantly indoor resting with some degree of exiphily



- Majority tribal population living in hilly and forested environment with criss-crossing perennial streams, depending on traditional form of agriculture, - cultivation in terraced fields on river beds - **all providing vast sources for vector breeding/ production and longevity.**

- Poor housing, mixed dwelling, hamlets surrounded by vast vector breeding grounds, scantily clothed, outdoor sleeping habit, slash and burn type cultivation on hill slopes - crop guarding, Mahua flower collection, engaged in collection of forest products - **leading to increased exposure, favourable resting shelter for vectors.**



- Surveillance started in 1961 and being continued
- Malaria positives detected and treated early - mainly chloroquine and primaquine
- Surveillance and treatment strengthened introducing RDTs (2005 and 2013), ACT (2006) and various mechanisms/strategies for effective coverage.
- Although there had been reduction in malaria incidence, did not come down beyond certain level.
- API remained to be more than API 10. Malaria deaths occurred - in adult age group also.

- Thus, there had been **persistent transmission** inspite of control efforts.

Vector control

- Before 1930, mostly environmental and anti-larval measures - deforestation and cultivation

- Antil-larval measures in project areas e.g. Railways - classical vector control **aiming to reduce vector density.**

- Pyrethrum spray (no residual effect) in limited areas.

- I944 - DDT trial followed by introduction of DDT indoor residual spray in NMCP (1956) and NMEP (1958) - **aiming at reducing the longevity of the vector population.**

- IRS was continued as the main vector control measure until LLIN was introduced.

Vector Control in India (IVM)

- Indoor residual spraying (DDT, Malathion and synthetic pyrethroids) and ITNs/LLINs in rural areas

- Anti-larval operations in urban areas (Source reduction, Temephos, Biocides and larvivorous fishes)

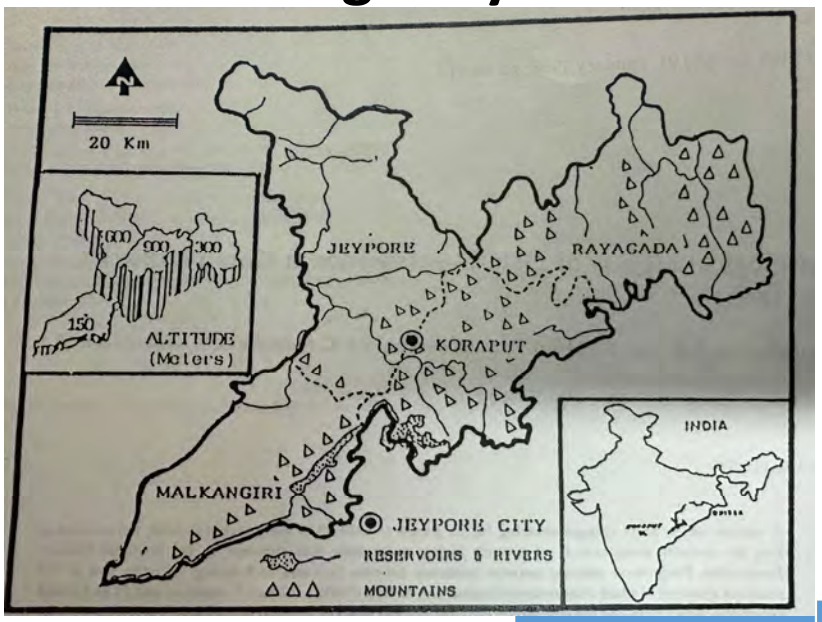
- *DDT selectively used, now phased out*

Reason for persistent transmission

- Difficult terrain, poor communication and transport facilities - inadequate service delivery, mud plastering of houses, faith in traditional medicine, poor health seeking behaviour - remained as hard-to-reach areas - **Inaccessible malaria.**

- **Consequently, drug resistance (CQ) and insecticide resistance emerged.**

Heterogenity in the malaria incidence/prevalence in the hill tract



- Zones at different altitude levels having varied climatic conditions (minimum and maximum temperature range and total rainfall) - **Variations in malaria seasonality and in vector abundance and seasonality.**

- Ecotypes: Plain, Riverine, Foothill and hill top villages/hamlets

Ecotype	Major vector	Transmission	Endemicity	Malaria incidence
Plain	*An.culicifacies*	Seasonal	Low	<API
Riverine	*An.culicifacies*	Seasonal	Low	<API
Foothill	An. *fluviatilis*	Perennial	Moderate - High	API>
Hill top	*An. fluviatilis*	Perennial	High	API>

Malaria incidence in two different zones and ecotypes

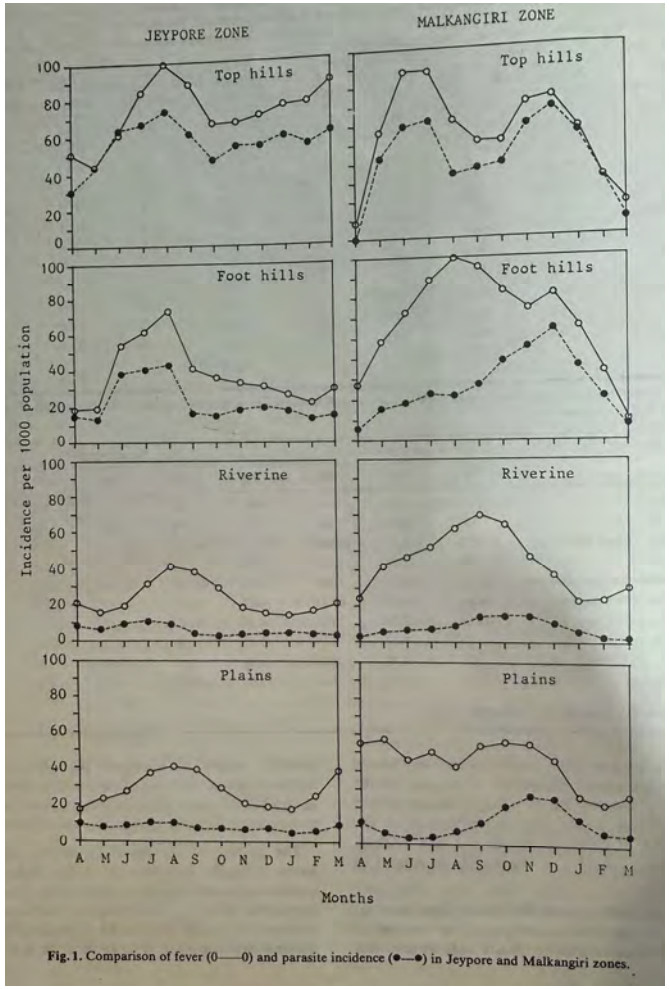
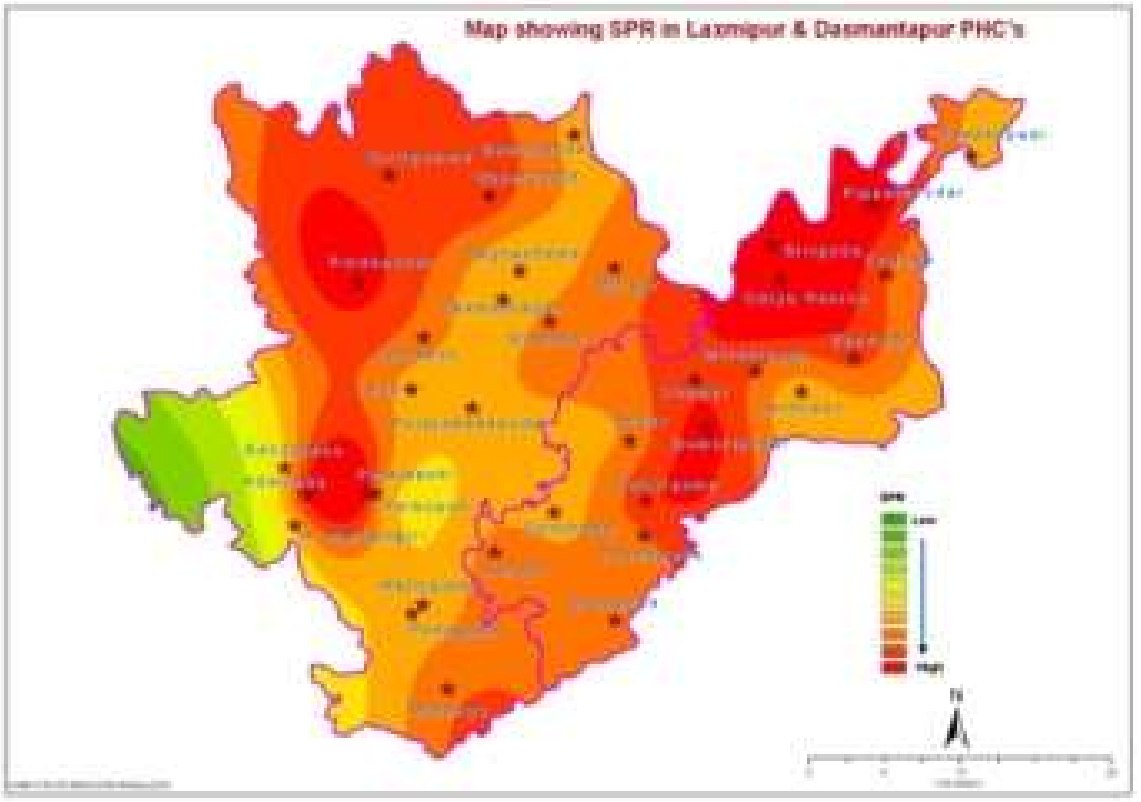


Fig. 1. Comparison of fever (0——0) and parasite incidence (•—•) in Jeypore and Malkangiri zones.

Malaria prevalence in CHC areas



Sites of malaria transmission

Indoor transmission: Vector rests indoor, predominantly in human dwelling as well as outdoors - vary with the altitudinal zones (Malkangiri), availability of vegetation and outdoor shelters. Vector bites throughout night, Biting time varies with season.

Outdoor transmission: Vector rests predominantly outdoors in Koraput Zone. Outdoor sleeping habit of the population depends on the season. Vector follow the activity of the residents. Biting time varies with season.

Extra-domicillary transmission: Receive infective bites while sleeping in the field during harvest seasons, sleeping on machaans to guard the crops, entering into forest fringes to collect moghu flowers and forest produces.

Transmission in labour camps: During dam construction, hydro-electric project etc. - vocational movement took place, people stayed in temporary shelters along the reservoir or river side with high receptivity.

Changing scenario - hope for elimination

- Changes took place following the introduction of Synthetic pyrethroids and ITN/LLIN - a strategy that **directly affects man-vector contact** and additionally vector density and longevity.

- Universal coverage of LLIN (Access)

- Intensified surveillance and treatment (ASHAs) - introduction of new diagnostics (RDT) and anti-malarial drugs (ACT).

- Full regimen (PQ) for the treatment of *P. vivax.*

- *Effective tools that can be effectively used - Launched Malaria Elimination Programme in 2017*

Category 3 states/UT (10) with API >1
(Base year 2014)

State/ UT	Population at risk (in 000s)	Total districts	Total positive cases	Pf%	ABER	API	SPR	Deaths
A & N Islands	466	3	557	20%	16.07	1.20	0.74	0
Dadra & Nagar Haveli	409	1	669	13%	17.54	1.64	0.93	1
Chhattisgarh	27 349	27	128 993	84%	14.42	4.72	3.27	53
Jharkhand	35 253	24	103 735	45%	9.63	2.94	3.06	8
Madhya Pradesh	77 041	50	96 879	43%	13.35	1.26	0.94	26
Odisha	43 501	30	395 035	87%	14.60	9.08	6.22	89
Meghalaya	3 128	7	39 168	95%	13.99	12.52	8.95	73
Mizoram	1 116	9	23 145	91%	29.65	20.74	6.99	31
Tripura	3 862	8	51 240	97%	15.71	13.27	8.44	96

- *Malaria elimination* is defined as **interrupting** local mosquito-borne malaria **transmission** in a defined geographical area, i.e. zero incidence of locally contracted cases.

- *Malaria eradication* is defined as the **permanent reduction to zero** of the **worldwide incidence of malaria infection** caused by a specific agent; i.e. applies to a particular malaria parasite species.

- The two new interventions introduced in malaria endemic areas of Odisha state during mid 2017 included
- - **universal coverage of long-lasting insecticidal nets (LLINs)** (11.13 million) in 17 high endemic districts and
- -‘’Durgama Anchalare Malaria Nirakaran’’ (elimination of malaria in inaccessible regions) **(DAMaN) -** targeting asymptomatic cases and low density infections (**to eliminate residual transmission)**
- After implementation of NSP, Odisha state observed a drastic reduction of malaria cases 81% in 2018 and 88.6% in 2019, compared to 2017.
- In Koraput District, there was 88.3% decline in malaria incidence during 2019 (4609 malaria cases, **API: 3.1**) compared to 39,173 in 2017 (**API: 26.4**) after implementation of NFME plan in the district

Change in vector abundance and behaviour (After LLIN coverage)

- Drastic reduction in vector density, *An. fluviatilis*
- Shifting the daytime indoor eating shelter - human Dwelling to cattle shed
- Shifting from anthropophagy to zoophagy - Drastic reduction in HBI
- *An. fluviatilis* is still susceptible to Synthetic pyrethroids
- *An. culicifacies* resistant to all types of insecticides

Malaria Elimination - Objectives

Launched :2016
Base Year: 2014

- **Eliminate** malaria from all 26 low (Category 1) and moderate (Category 2) transmission states/union territories (UTs) by **2022**
- **Reduce the API < 1** in all districts (states and UTs) by **2024**
- **Interrupt indigenous transmission** of malaria throughout the entire country, including Category 3 by **2027**
- **Prevent the re-establishment** of local transmission of malaria and maintain national **malaria-free** status by **2030** and **beyond**

Classification of states/UTs based on API

Category 0: Prevention of re-establishment phase **Zero indigenous cases**

Category 1: Elimination phase Reporting **<1 API**

Category 2: Pre-elimination phase Reporting **<1 API,** but some districts reporting **>1 API**

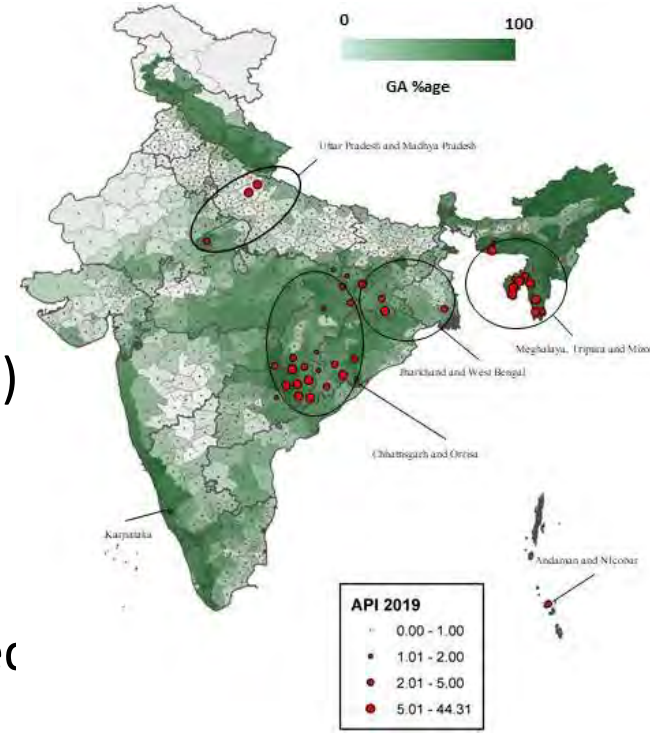
*Category 3: Intensified control phase Reporting **>1 API**

*Includes Odisha, Chattisgarh, Jharkand, Madhya Pradesh

Mostly, widespread hilly, tribal, forested and conflict-affected areas

Targets for Category 3 States/UTs (Intensified control phase - 2014)

- By 2020: Enter into pre-elimination phase (5/10 states)
- By 2022: Enter into elimination phase (5/10 states)
- By 2024: Enter into elimination phase (remaining 5 states)
- By 2027: Indigenous transmission interrupted (All).
- By 2030: Re-establishment of local transmission prevented Malaria-free status maintained.



Pre-elimination Phase: API >1
Elimination Phase: API <1

- Are there indications of resurgence during 2021-23?
- Odisha reporting > 33,500 malaria cases (P.f cases: > 27,0000 and 4 deaths in 2023.
- There are districts that maintain the reduction in the overall API, but certain CHC areas are still highly endemic.

- Shall we reach the target by 2030?