Mosquito Essentials:

the basis for malaria prevention

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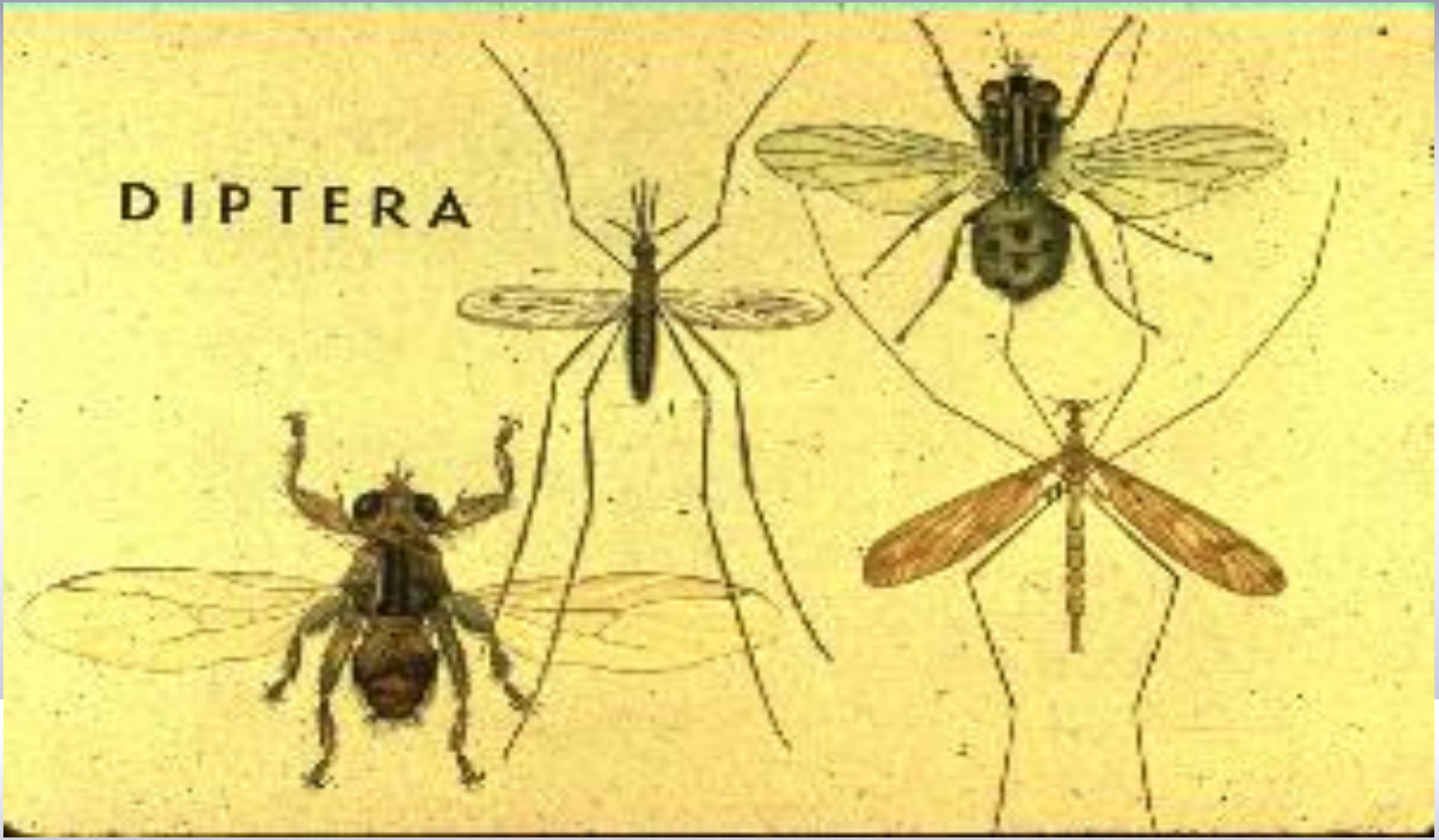
Objective:

Appreciate mosquito ecology as the basis of vector control strategies and prevention messages.

Mosquito Essentials

- Mosquito taxonomy and recognition
- Life cycle
- Breeding sites
- Seasonal and daily cycles
- Flight range
- Longevity
- Transmission dynamics

Taxonomy: Order Diptera



Important genera

- *Anopheles*
- Malaria / filariasis
- *Aedes*

Esp. *Aedes aegypti*

- Dengue/ Yellow Fever
- *Culex*
- Arbovirus/ filariasis

Current classification of the 142 Afrotropical species

Anopheles

Anopheles

Myzorhynchus
- An. coustani
- An. crypticus
- An. caliginosus
- An. fuscicolor
- An. namibiensis
- An. paludis
- An. symesi
- An. tenebrosus
- An. ziemanni
- An. obscurus

Anopheles
- An. concolor

Christya
- An. implexus
- An. okuensis

Cellia

Neomyzomyia
- An. smithii
- An. caroni
- An. dualaensis
- An. faini
- An. hamoni
- An. jebudensis
- An. lovettae
- An. rageaui
- An. vanhoofi
- An. wilsoni

- An. grassei
- An. grenieri
- An. griveaudi
- An. lacani
- An. mascarensis
- An. milloti
- An. notleyi
- An. pauliani
- An. radama
- An. ranci
- An. roubaudi

- An. ardensis
- An. buxtoni
- An. carnevalei
- An. cinctus
- An. deemingi
- An. dureni
- An. kingi
- An. machardyi
- An. maliensis
- An. millecampsi
- An. natalensis
- An. nili
- An. somalicus
- An. vernus
- An. vinckei

- An. r. rhodesiensis
- An. r. rupicolus
- An. cameroni
- An. lounibosi
- An. rhodaini
- An. ruarinus

Myzomyia
- An. azaniae
- An. barberellus
- An. brunnipes
- An. culicifacies
- An. domicola
- An. dthali
- An. erythraeus
- An. ethiopicus
- An. flavicosta
- An. fontinalis
- An. longipalpis
- An. m. bervoetsi
- An. m. moucheti
- An. schwetzi
- An. tchekedii
- An. walrawensi

- An. funestus
- An. aruni
- An. parensis
- An. vaneedeni
- An. brucei
- An. confusus
- An. fluviatilis
- An. fuscivenosus
- An. leesoni
- An. rivulorum

- An. marshallii
- An. letabensis
- An. hughi
- An. austenii
- An. berghei
- An. brohieri
- An. gibbinsi
- An. hancocki
- An. hargreavesi
- An. harperi
- An. kosiensis
- An. mortiauxi
- An. mousinhoi
- An. njombiensis
- An. seydeli

- An. w. wellcomei
- An. w. ugundae
- An. w. ugunjae
- An. erepens
- An. distinctus
- An. theileri

- An. demeilloni
- An. carteri
- An. freetownensis
- An. garnhami basilewskyi
- An. garnhami
- An. keniensis
- An. lloreti
- An. s. sergentii
- An. s. macmahoni

Pyretophorus
- An. chrystii
- An. comorensis
- An. daudi
- An. gambiae
- An. arabiensis
- An. quadriannulatus
- An. bwambae
- An. melas
- An. merus

Paramyzomyia
- An. c. cinereus
- An. c. hispaniola
- An. turkhudi
- An. azevedoi
- An. listeri
- An. multicolor
- An. courdurieri

Neocellia
- An. dancalicus
- An. hervyi
- An. maculipalpis
- An. pretoriensis
- An. r. rufipes
- An. r. broussesi
- An. salbai

Cellia
- An. argenteolobatus
- An. brumpti
- An. cristipalpis
- An. cydippis
- An. murphyi
- An. pharoensis
- An. squamosus
- An. swahilicus

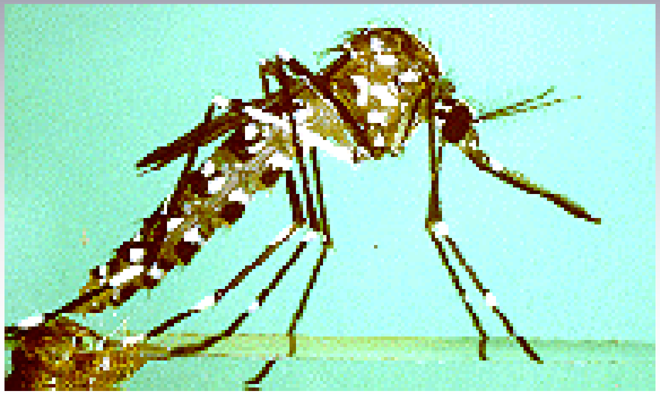
Anopheles Genus
Anopheles .... Subgenus
Myzorhynchus .... Series
An. smithii .... Type of a section
An. coustani .... Species
An. fuscicolor .... Malagasian endemic

modified from Gillies & Coetzee, 1987

Issue for Control #1

- Many types of mosquitoes, but in Africa, only three transmit malaria:
  - *Anopheles gambiae*
  - *Anopheles arabiensis*
  - *Anopheles funestus*

Mosquito life cycle



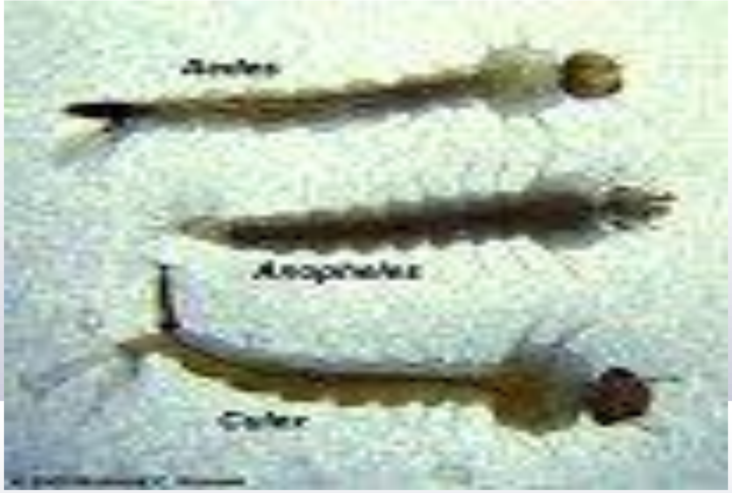
Ecological differences: egg

Aedes: glued to container wall above water

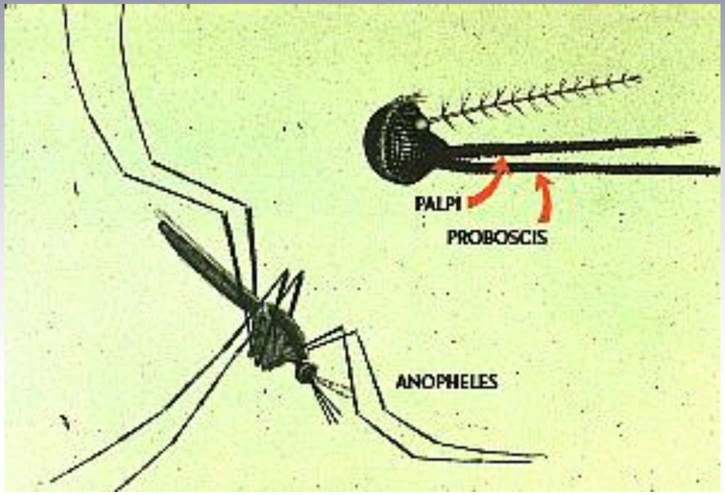
Anopheles: single on top of water

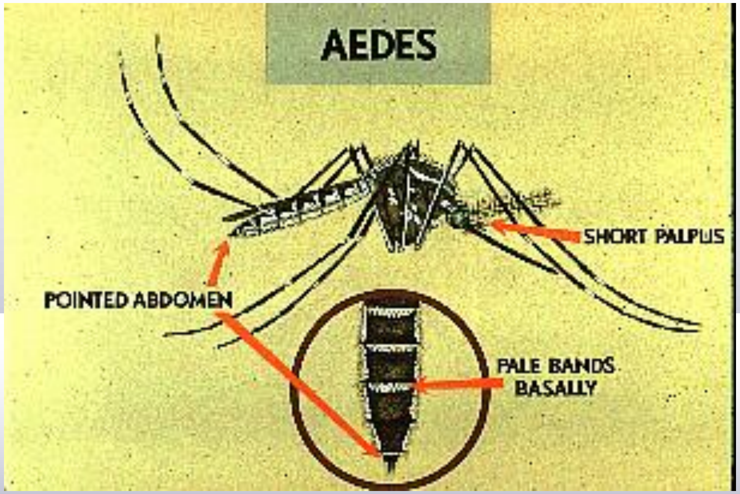
Culex: rafts on top of water

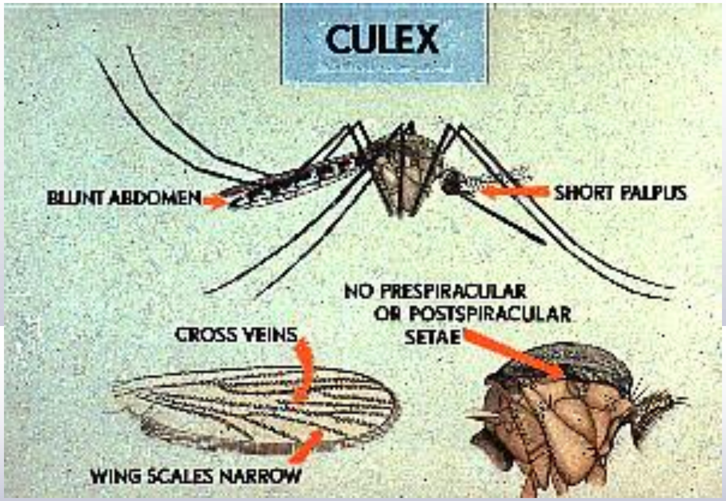
Identification: larvae



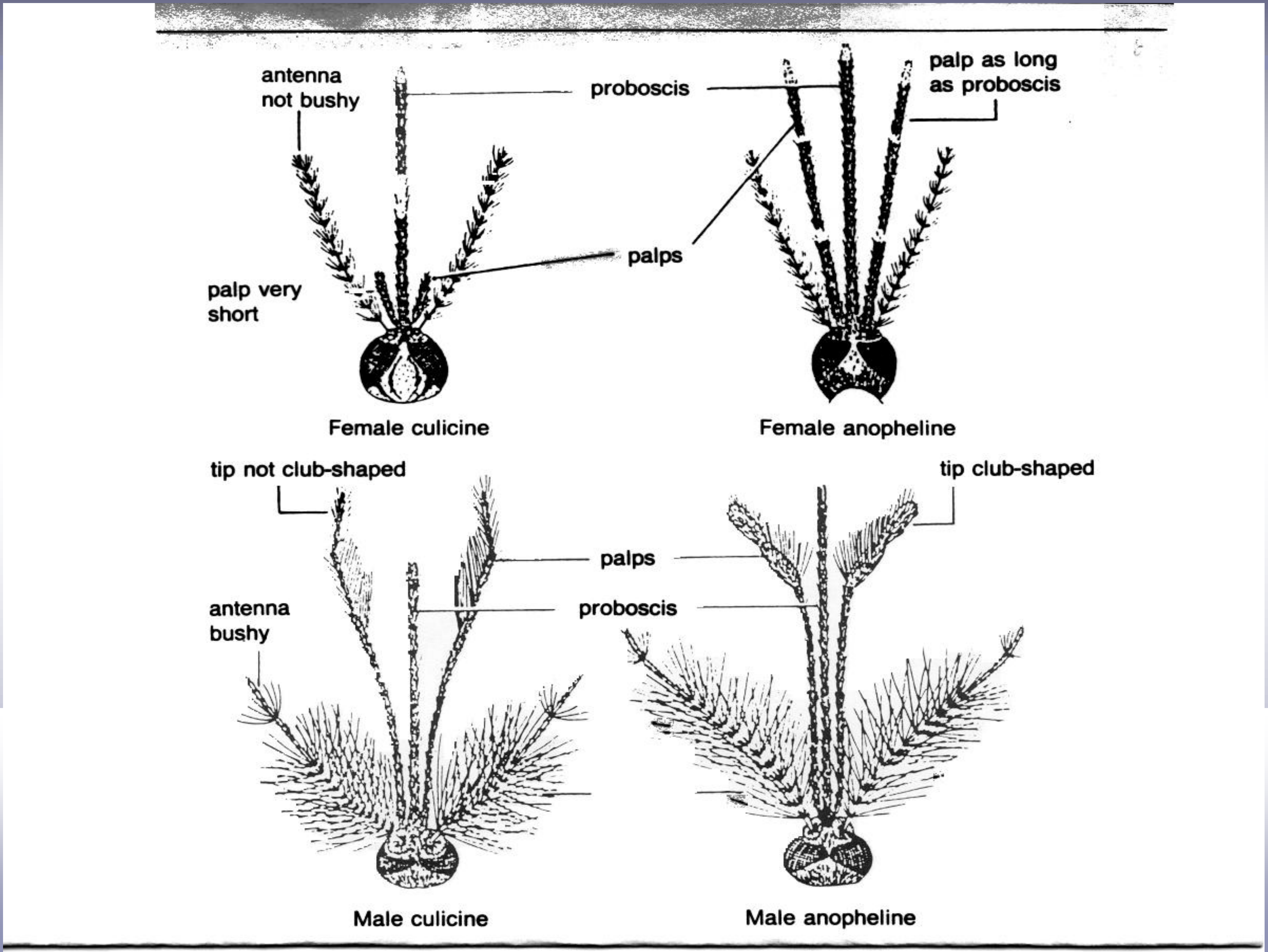
Identification: adult







Adult Identification



Culex breeding sites: Polluted ground water

Aedes aeypti: container breeder

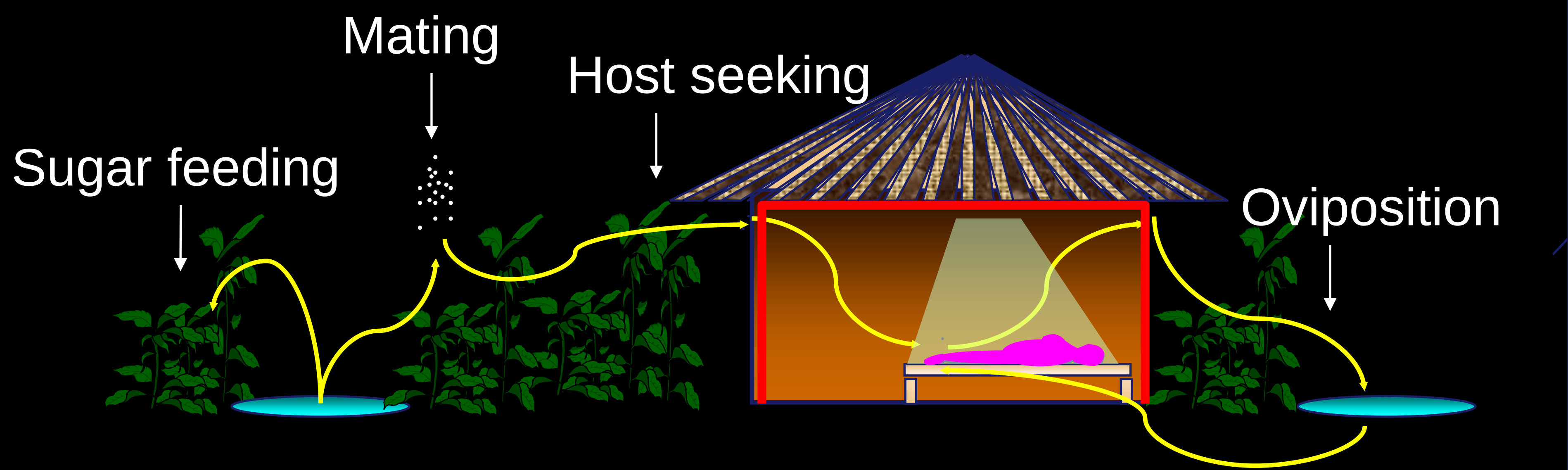
Anopheles: clear ground water

Issue for Control #2

- Different mosquitoes, different breeding sites:
  - *Aedes* – containers
  - *Culex* – dirty ground water (urban)
  - *Anopheles* – clean ground water, often small footprints, wheel ruts etc:

Difficult to find and eliminate all Anopheles breeding sites. Cleaning containers is for Aedes (dengue) not Anopheles (malaria)

Life History and intervention points



Residual Spraying

Insecticide Treated Bed Nets

Locating the host

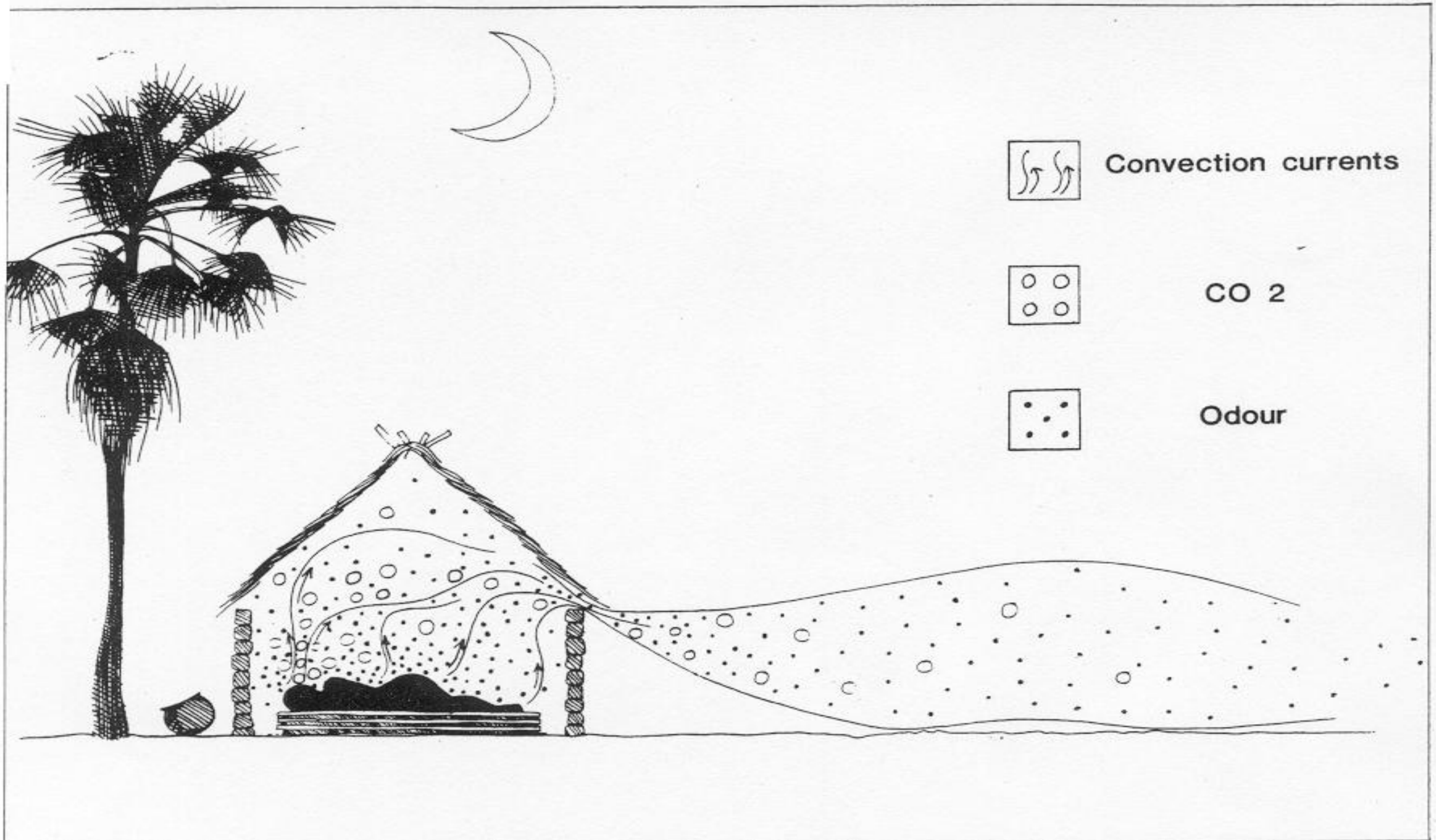


Fig. 16.3 How a sleeping host presents itself to the searching mosquito

Flight Range

- *Aedes*

  < 1 km

- *Anopheles*

  1.5 – 2 km

- *Culex*

  5 – 7 km

Slashing Grass

Bull. Ent. Res. 37 1946-47 33

EFFECTS OF BUSH CLEARANCE ON FLIGHTING OF WEST AFRICAN ANOPHELINES.

By Major C. R. Ribbands, R.A.M.C.

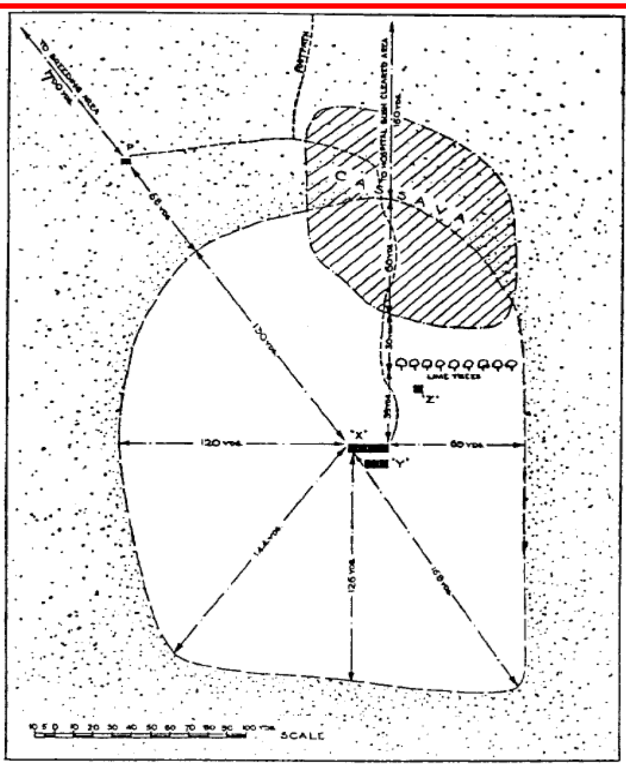
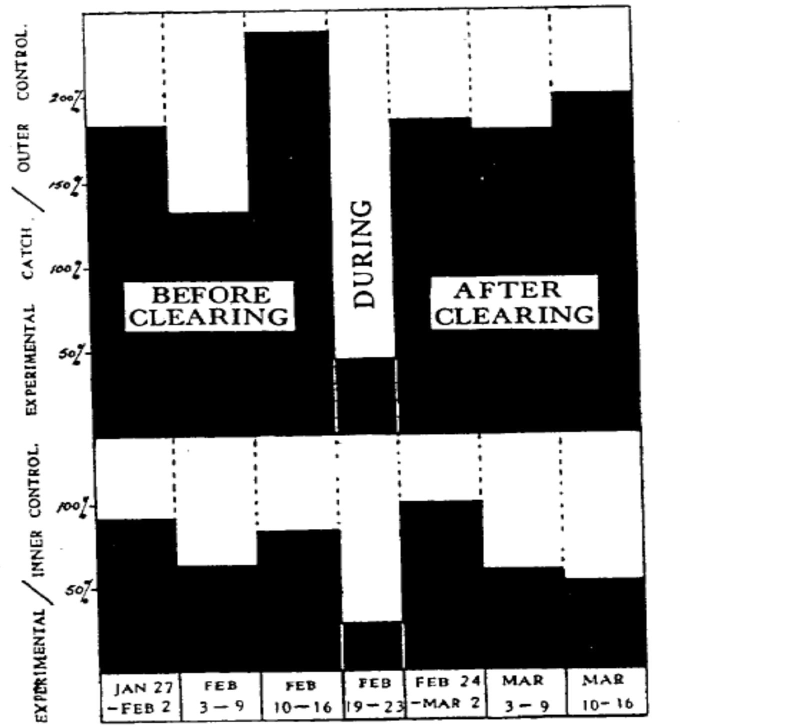


Fig. 1.—Plan of experimental area at Krabonekrom. The cleared area has been left unstippled.



Proportions of ♀ *A. funestus* in cleared area before, during and after bush clearance.

Slashing Grass: debunked in 1947

BUSH CLEARANCE AND FLIGHTING OF ANOPHELINES. 41

Summary.

1. Two huts were selected which were surrounded by dense bush, which varied in height from 4 to 15 feet. After elimination of this bush within a radius of 140 yards from these huts, the proportion of the population of ♀ *A. funestus* and ♀ *A. gambiae* attracted to them was at least 90 per cent. of the proportion which reached them before the bush clearance. This result indicates that bush clearance is not a justifiable measure for reducing Anopheline infestation. Even the male Anophelines entered the cleared area in the same proportion as they did before clearance.

Slashing Maize

Related Articles, Links

Med J Zambia. 1978 Aug-Sep;12(4):101-2.

Do mosquitoes breed in maiza plant axils?

Watts T, Bransby-Williams WR.

One thousand five hundred and seven tasselled maize plants in Lusaka and 96 in a rural village where mosquitoes were plentiful, have been surveyed. About 28% of plants contained water mainly around developing cobs. No mosquito larvae were found. It is concluded that maize slashing as part of the programme for malaria control is unjustified.

PMID: 44931 [PubMed

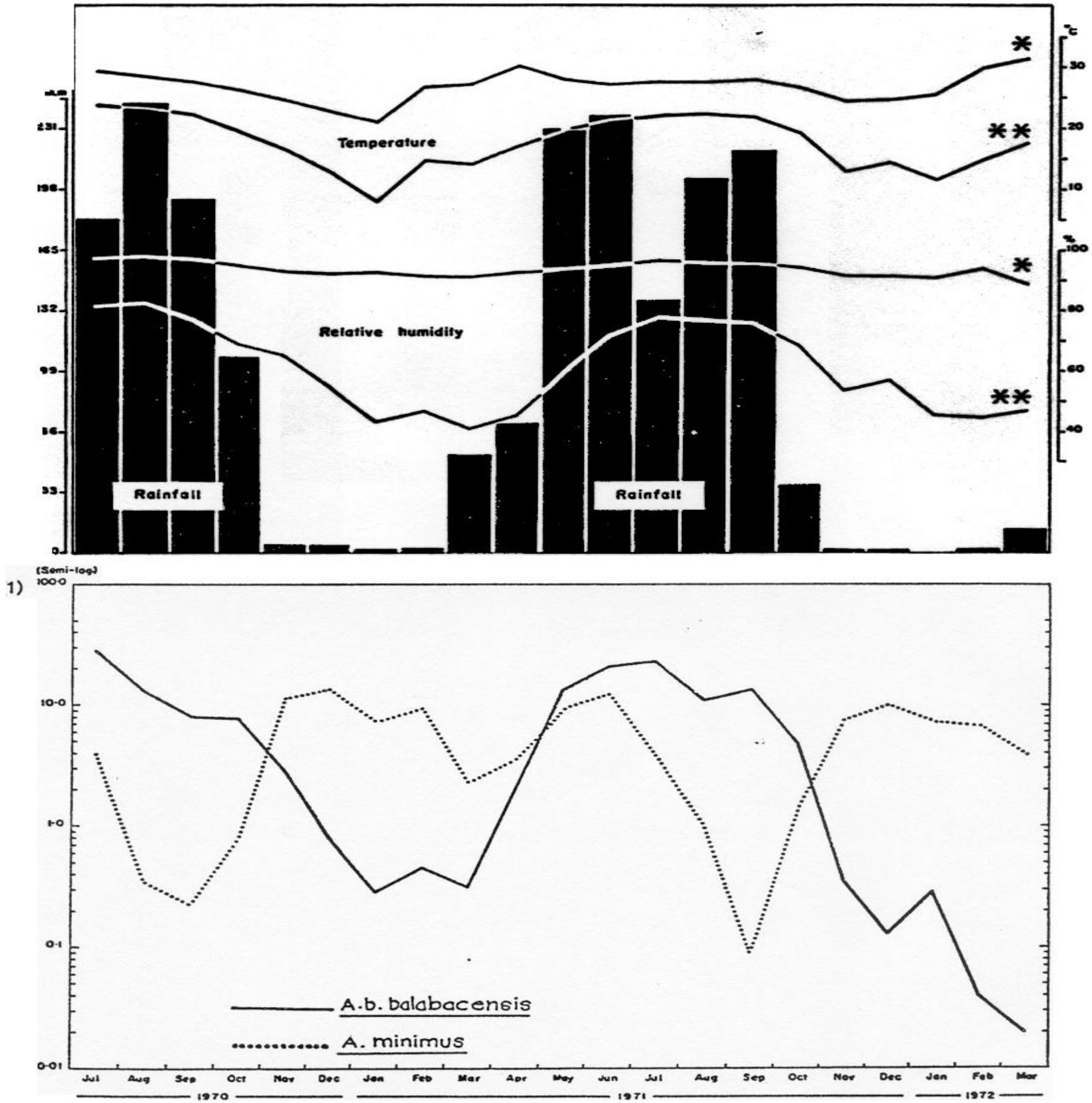
Issue for Control #3

- Anopheles can fly 2 km to find host:
  - *All* Breeding sites within that zone must be eliminated
  - Slashing grass and maize has no impact on mosquito biting

Seasonal and daily rhythms

- Seasonal – rains and temperature

- *An balabacensis* and *An minimus*



(1) Average no. of bites per man/night
* mean maximum temperature and mean maximum relative humidity
** mean minimum temperature and mean minimum relative humidity

Issue for Control #4

- **Different mosquitoes may peak in different seasons. The malaria vector may be present during the dry season when other mosquito populations are low.**

It is important to use an ITN throughout the year

Biting time, Africa

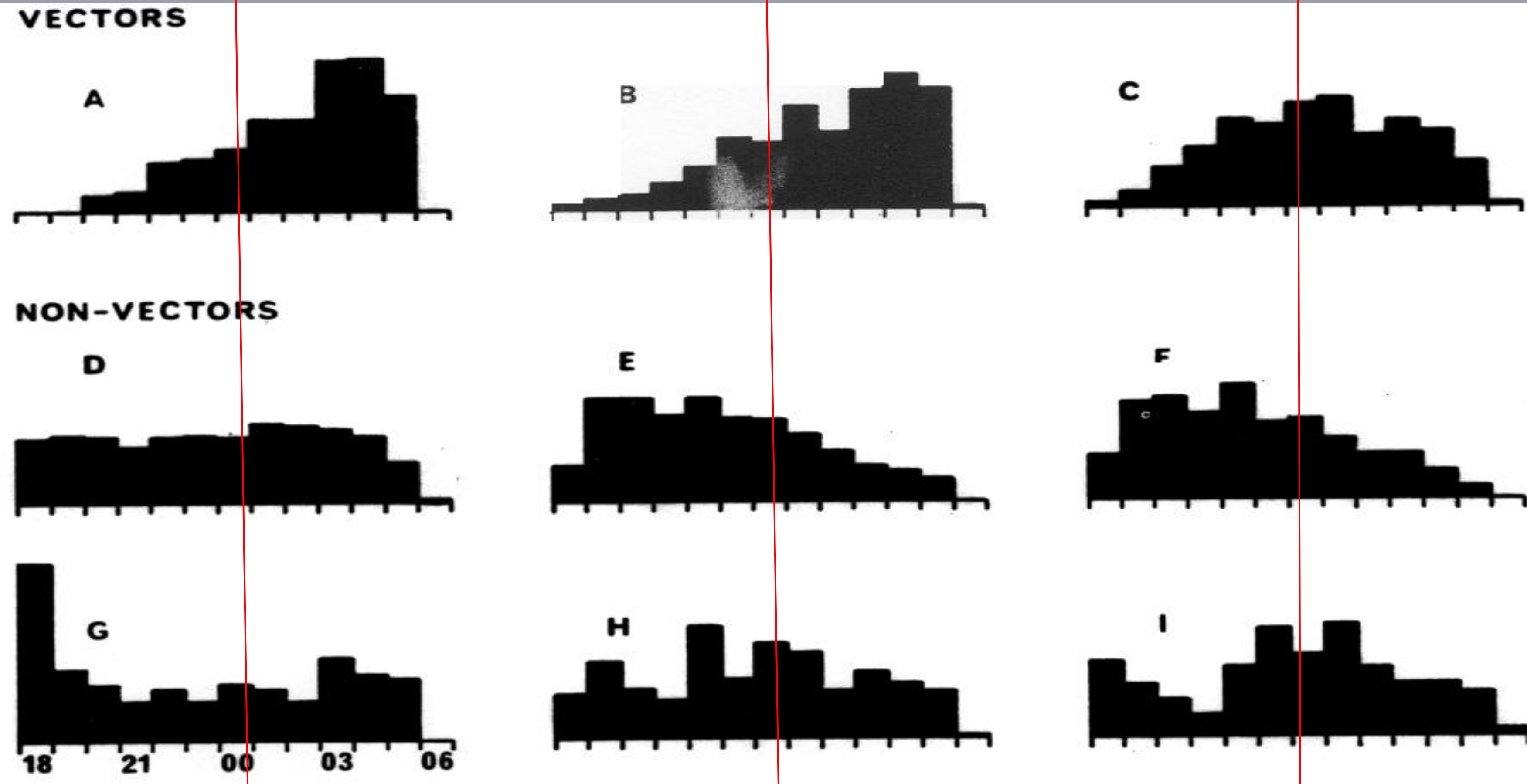
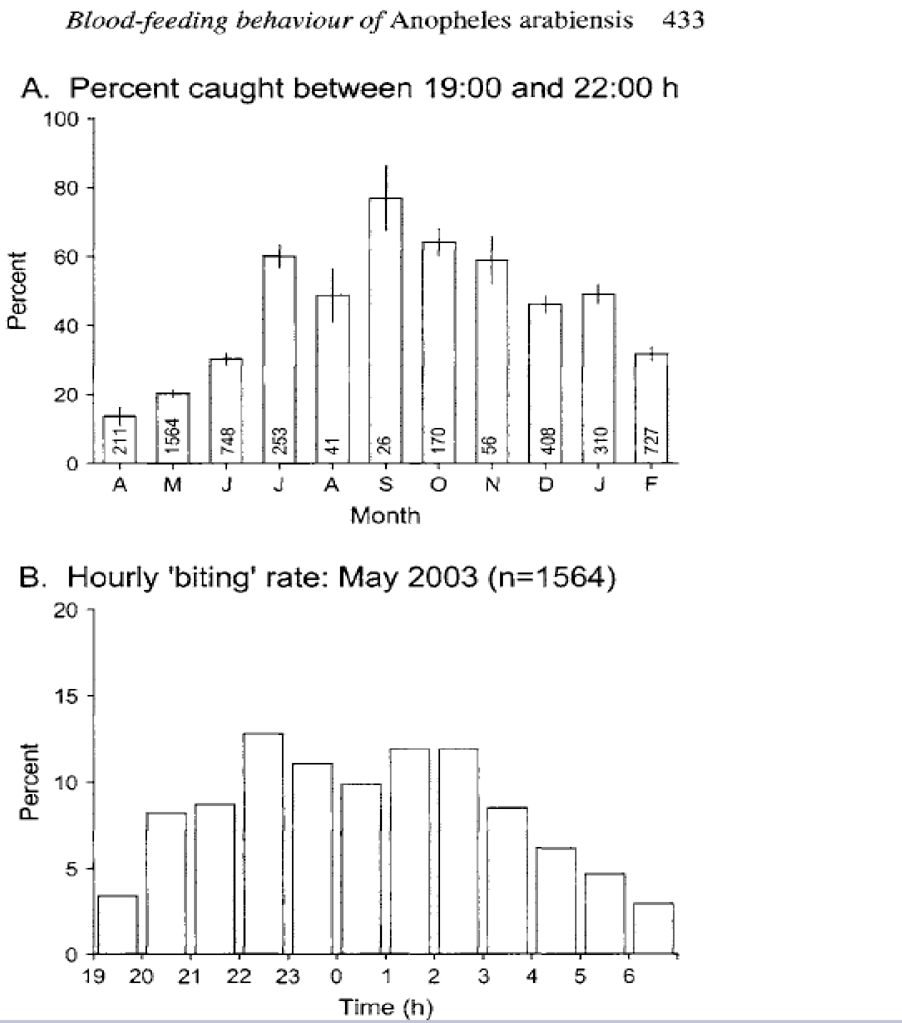
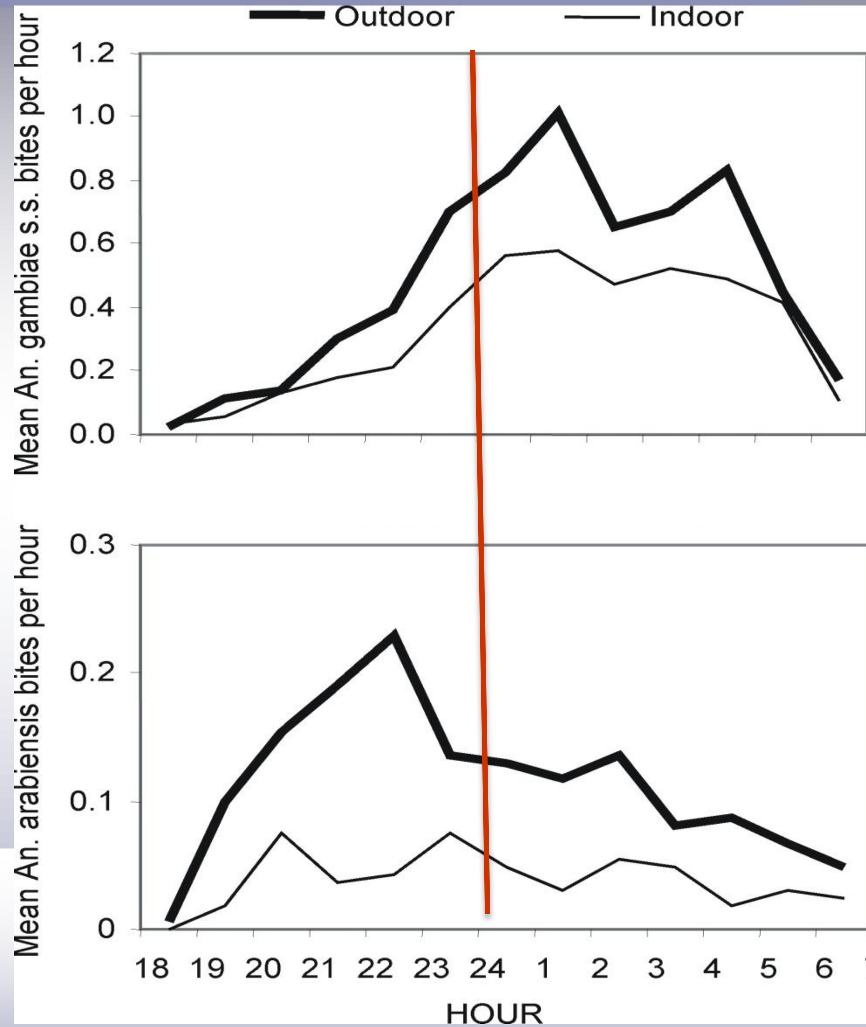


Fig. 16.5 Biting cycles of African *Anopheles* in Upper Volta.
Vectors: A—*A. gambiae* s.l.; B—*A. funestus*; C—*A. nili*.
Non-vectors: D—*A. coustani* gp.: E—*A. pharoensis*; F—*A. wellcomei*; G—*A. squamosus*; H—*A. flavicosta*;
I—*A. brohieri* (Adapted from: Hamon 1963b)

Biting times problem: *An arabiensis*





Tirados et al 2006

Geissbühler et al 2007

Issue for Control #5

- *An. gambiae* and *An. funestus* feed late at night: 22:00 to 04:00
- *An arabiensis* may feed somewhat earlier
- The mosquitoes biting during the day and evening are not malaria vectors

Therefore ITNs work

Transmission Dynamics

Parasite incubation period in the mosquito and mosquito longevity

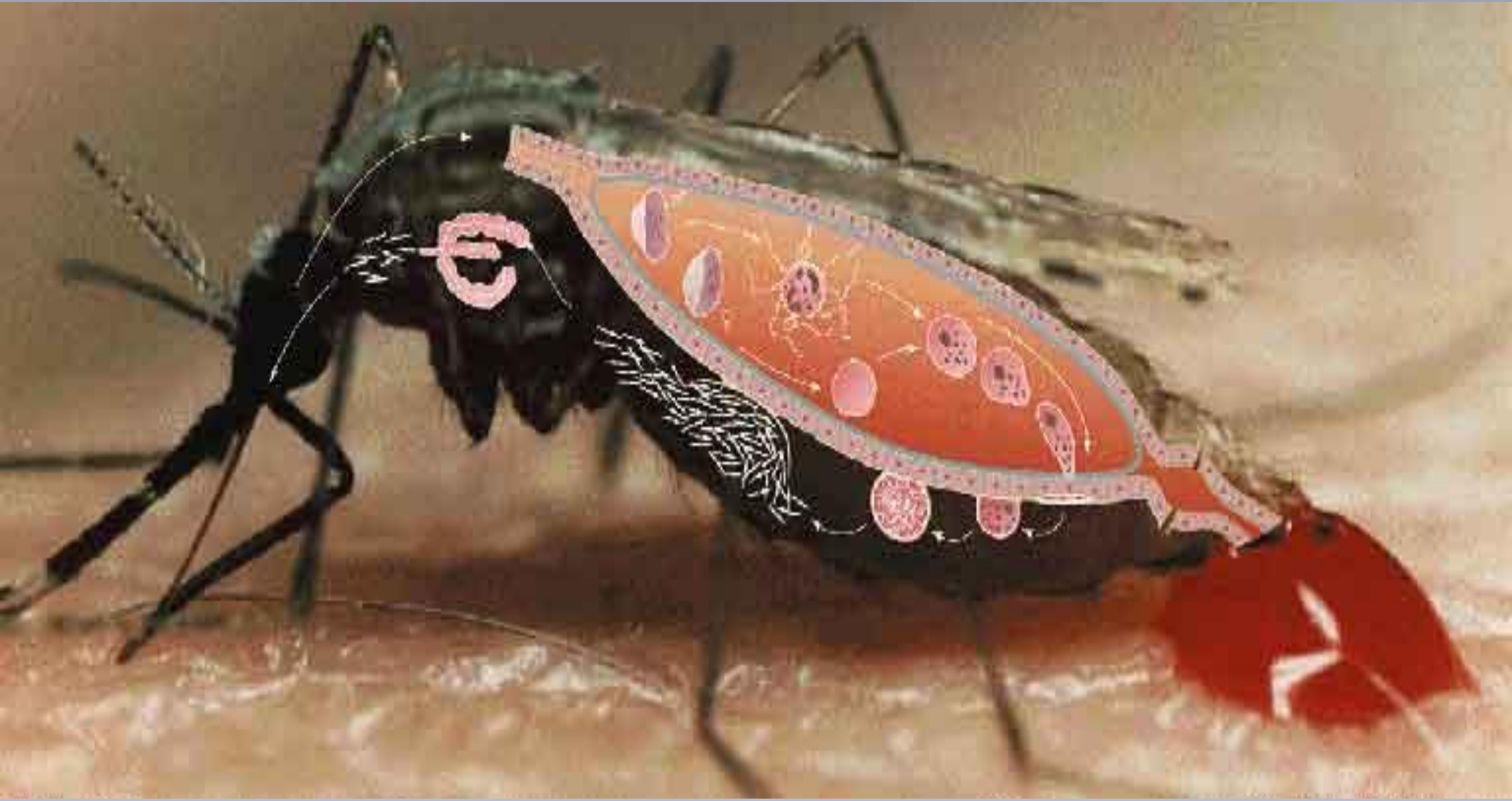
or

The time to infectivity

Vs

The time to death

Plasmodium Cycle in mosquito



Incubation period and temperature

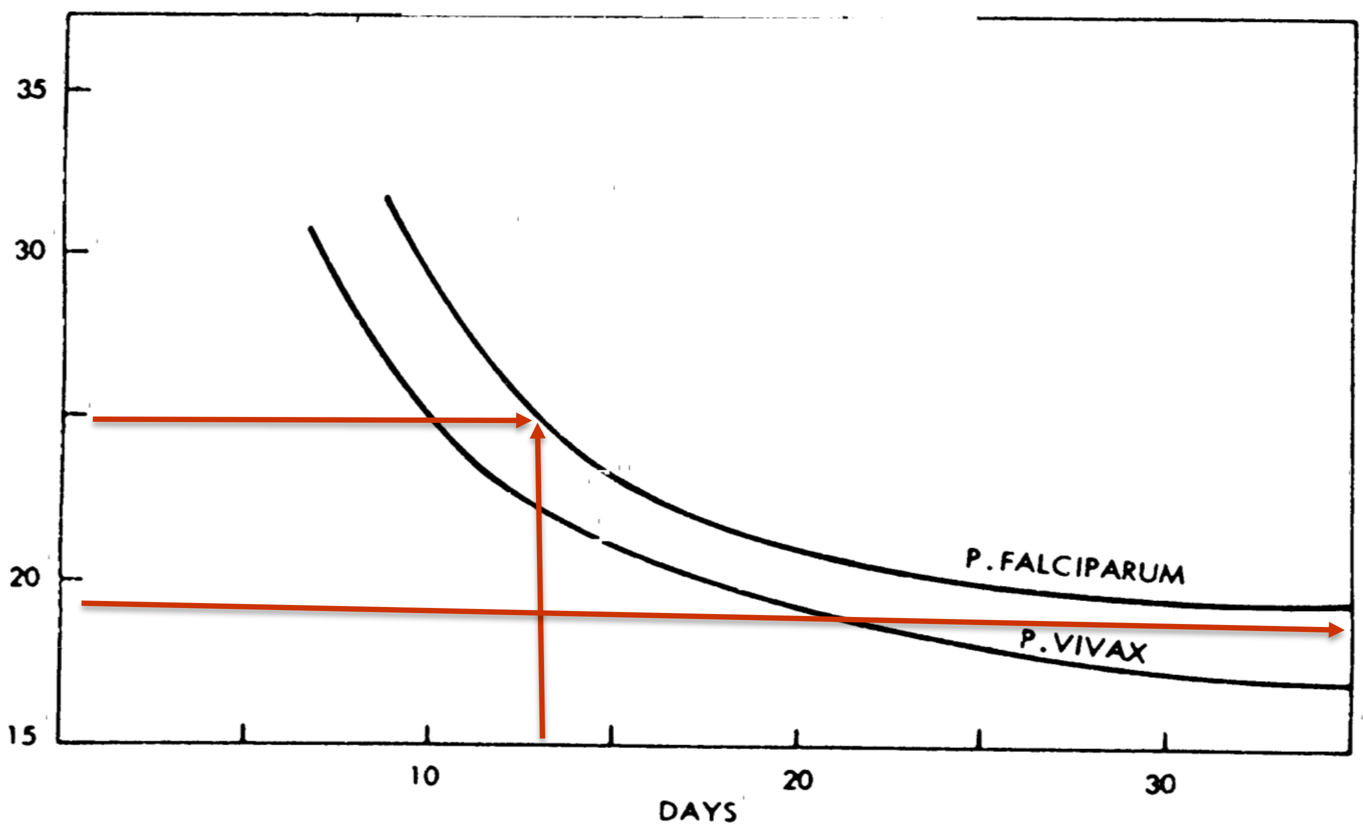


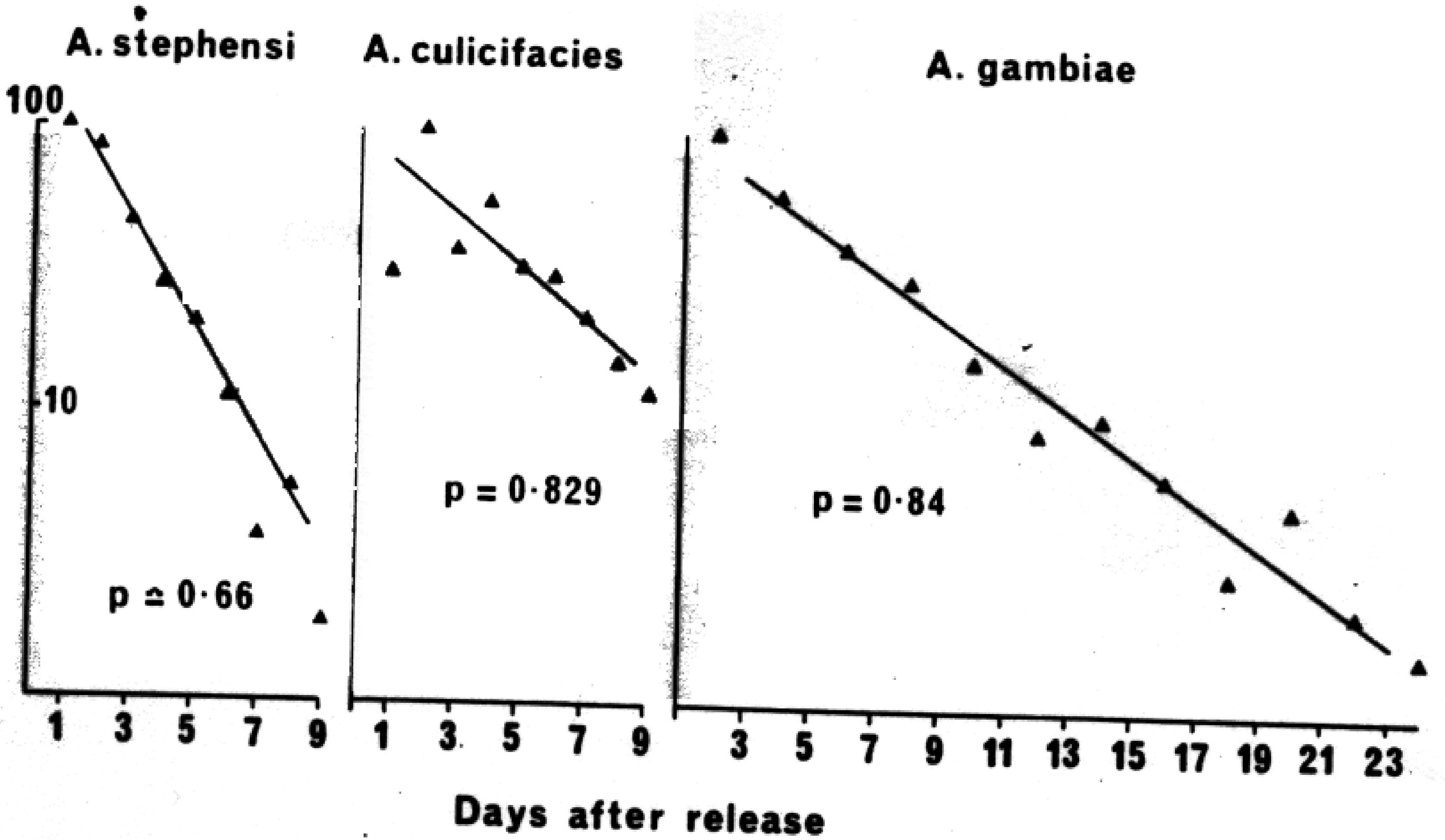
Fig 42 Duration of sporogonic (extrinsic) development of malaria parasites in Anopheles in relation to the environmental temperature. (Macdonald, 1957)

Issue for Control #6

- **At 25º it takes 12 days before a mosquito can transmit malaria – most will die before then. Below 19º malaria can not be transmitted.**

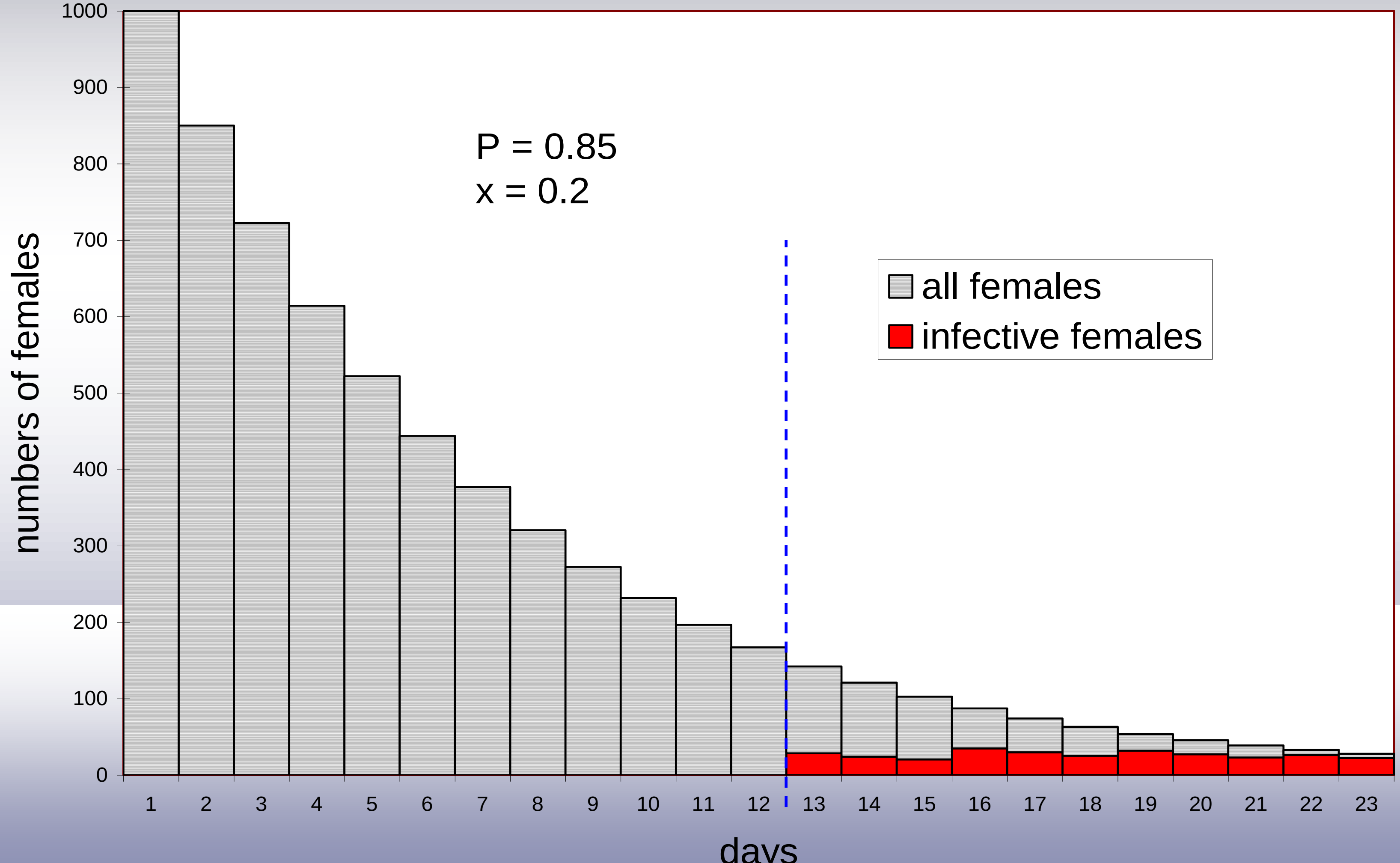
Malaria falls off in "winter" (e.g. Zambia) because of the cooler temperature, but can happen as temperature increases before the rains as long a there is ground water

Longevity (daily survivorship)

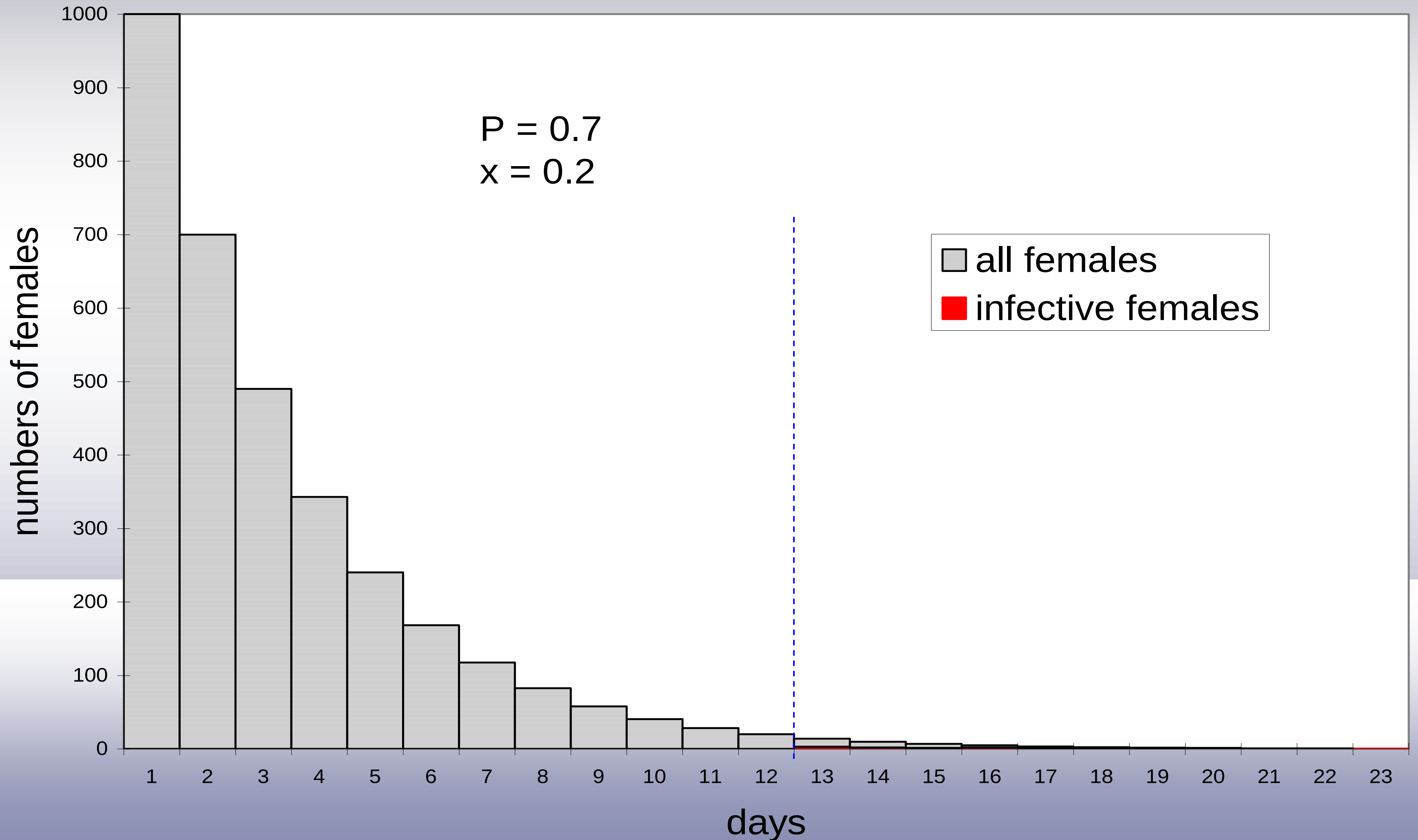


g. 16.8 Survivorship curves of marked recaptures of three vectors. p = probability of survival through one day. (From: uraishi et al 1966; Rawlings et al 1981; Gillies 1961)

Daily survivorship and transmission potential



small change in daily survivorship = big change in transmission

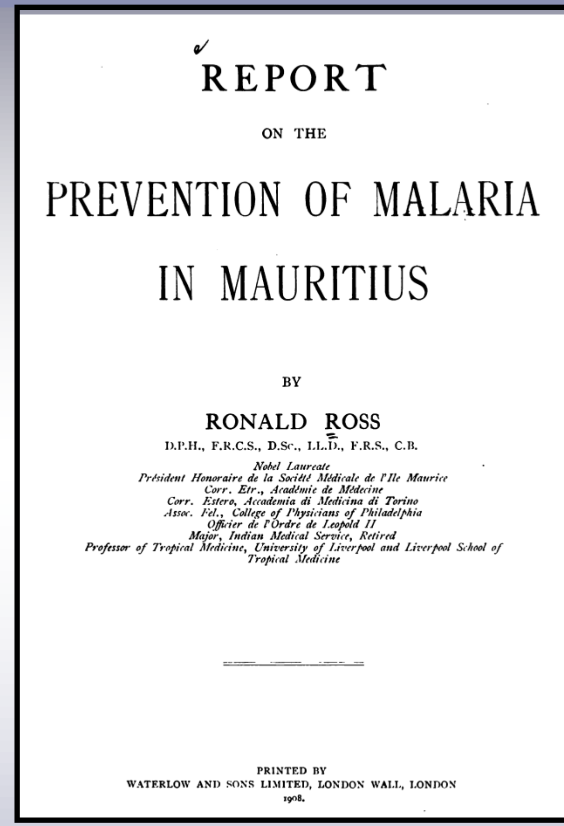


Issue for Control #7

- **Mosquitoes don’t live very long – most will die before they can transmit malaria.**

A small change in the daily survivorship can have a big impact on transmission potential

Ronald Ross: *Theory of Happenings*



REPORT

ON THE

PREVENTION OF MALARIA

IN MAURITIUS

BY

RONALD ROSS

D.P.H., F.R.C.S., D.Sc., LL.D., F.R.S., C.B.

Nobel Laureate
Président Honoraire de la Société Médicale de l'Ile Maurice
Corr. Etr., Académie de Médecine
Corr. Estero, Accademia di Medicina di Torino
Assoc. Fel., College of Physicians of Philadelphia
Officier de l'Ordre de Leopold II
Major, Indian Medical Service, Retired
Professor of Tropical Medicine, University of Liverpool and Liverpool School of Tropical Medicine

PRINTED BY
WATERLOW AND SONS LIMITED, LONDON WALL, LONDON
1908.

Such calculations as these, which may appear far-fetched to many, are useful, not so much for the numerical estimates yielded by them, but because they give more precision to our ideas and a guide for future investigations.

Ross Malaria Model

$$\begin{tikzcd} \boxed{1 - y} \arrow[r, shift left, "C\,y"] & \boxed{y} \arrow[l, shift left, "r"] \end{tikzcd}$$

y = fraction infected/infectious

r = recovery rate

C = Vectorial Capacity

Equilibrium Prevalence

$$y = 1 - \frac{r}{C}$$

"…a limit must be reached when the new infections exactly balance the recoveries." (Ross, 1910 pg 164)

Vectorial Capacity

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

human biting rate (ma)

human biting habit (a)

estimated infective life(p^n/ $-\ln p$)

Insight #1 Sensitivity analysis *what has the most impact?*

- **Survivorship: p** **(p^n/ -rlnp)**

  IRS, mass effect of LLINs

- **Anthropophily: a** **(a^2)**

  nets and repellents

- **Population density: m** **(m)**

  Larval Source Management

The advantages of anti-adult methods of malaria vector control (IRS and ITNs) vs larval control

- **Amplified Effect on Transmission**
  - IRS and ITNs can reduce the intensity of malaria transmission by 50-fold even in routine conditions (80% coverage)
- **Long Duration of Residual Efficacy**
- **Standardised Methods**

Summary

- **Different mosquitoes: different ecologies and potential intervention points.**
- **Specific parameters important: longevity, human biting habit and density.**
- **There is a biological, ecological and mathematical basis to our strategies**