*SCHISTOSOMIASIS TRANSMISSION*

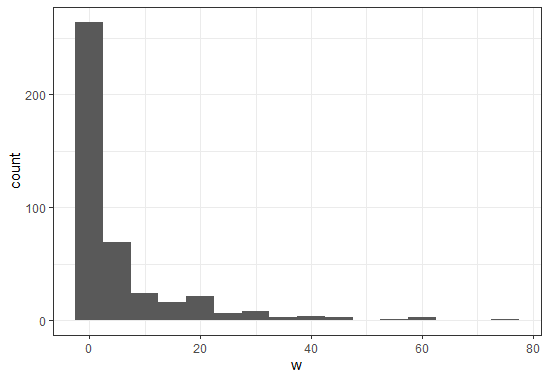
Timestep [1 month] *t*

Human hosts *i = 1, …, N*

**INITIAL POPULATION**

* Initial age distribution based on Uganda lifetables (first histogram)
* Initial worm distribution in the population (second histogram)





* Individuals are assigned with sex and individual susceptibility to infection (described below)

All the quantities presented with the subscript *i* refer to the *i-th* individual in the population.

At each timestep *t* the following events occur*:*

**DEMOGRAPHY**

At each time step, births, deaths and aging regulate the demography, according to birth rates and death probabilities available for Sub-Saharan Africa. The main **challenge** is to keep a constant size of the population. The parameters related to African demography describe an expanding population.

I explore this aspect using two different methods:

1. **The reaper.**

The number of **births** for the current monthis determined by a Poisson drawn with a rate given as:

where

is the crude **annual** birth rate for Sub-Saharan Africa (per **1000** individuals)

is the population size at timestep *t*

The population is updated with *#births* new individuals, assigned with age=0 and worm load=0. Sex and individual susceptibility are also assigned as described in the next section.

Each month individuals can dye according to an age- and sex- specific **death probability** available from the WHO Demography App for Sub-Saharan Africa.

In case of **death,** the individual is removed from the population.

**Updating age and population quantities:**

After births and deaths occurred, individual age is (monthly) incremented and population size, number of SAC and cumulative exposure accordingly updated.

The reaper (used in WORMSIM) occurs annually and all the times that the population size exceeds a given maximum value for population size, the population is reduced of 10%. This mechanism preserves the age distribution over time, but the population dynamics are totally dependent on the chosen input value.

To produce the plot below I am using the reaper mechanism with a max population of 700 individuals. Ten stochastic seeds (grey lines) with the mean (black line) are displayed.

**Population size over time**

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1. **Replacing dead individuals**

Each month individuals can dye according to an age- and sex- specific **death probability** available from the WHO Demography App for Sub-Saharan Africa.

In case of **death,** the individual is removed from the population and replaced by a new born: the age is set to zero, the sex re-assigned and the parasitological quantities reset. This mechanism keeps constant the population size (the same value as the initial population size), but it does not preserve the age distribution over time, since the births are not defined by an actual birth rate.

The two histograms below compare the **age** distribution for the initial population given a Sub-Saharan Africa demography (left panel) and the age distribution at the end of the simulation (500 years) (right panel), assuming only birth/death events and no transmission of the disease.



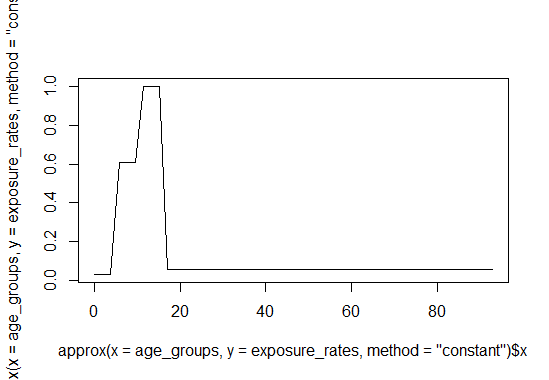
**EXPOSURE to infection**

**Force of infection acting on individual *i* : number of new worms acquired [nw]**

*cloud* = number of larvae in the reservoir

*zeta =* overall exposure rate (it mainly drives transmission --> the level of true prevalence)

= age-specific contact (exposure) rates



Age

Exposure rate

: aggregation level of worms, including individual propensities to infection. It has a range in Graham (2021). It drives the abundance of high intensities of infection.

individual susceptibility to infection. It is assigned at birth and lasts lifelong.

New worms are assigned sex. Random portion of new worms are male worms:

**WORMS**

**Mature worms are paired [wp]. Paired worms can produce eggs.**

, number of worm pairs

, expected egg load

: number of male mature worms for human host *i*

: number of female mature worms for human host *i*

: number of detected eggs from human host *i*

: fecundity in eggs/worm pair. Range studied in De Vlas (1992). It has effect on the shape/slope of the bounce backs.

: aggregation parameter for egg counts. It drives the “gap” between true prevalence and egg-based prevalence. Sake takes into account quantity of stool and repeated sample to quantify it.

***N.B.*** *In case the density dependency assumption applies, the individual expected egg load is defined as*

*With : density dependent fecundity. (Temporary assumption.) From Graham (2021).*

**CONTRIBUTION to the reservoir**

**Individual contributions []**

**CONTROL**

*(****MDA* assumptions*: 75% coverage, 80% efficacy, annual to pre-SAC and SAC, 10 years)***

If *t* is the time of MDA:

If age of individual *i* is in the target population:

}

**WORMS are updated for the next month:**

The new acquired worms are added, which will be considered mature the next month. (Assumption that can be improved).

A survival portion of males and females worms from the previous month is included.

*:* 1 - survival probability of worms from the previous month

: lifespan of an adult worm in the human host [years]

**RESERVOIR/CLOUD**

**Temporary assumption: general cloud without snails**

**OUTCOMES**

**Prevalence timelines**

1. True prevalence
2. Egg-based prevalence
3. Egg-based prevalence in SAC
4. Prevalence of high intensity of infections

Applying density-dependency assumption for egg production.

The implementation of a dynamic demography has introduced greater stochastic effect during the burn-in, the runs however stabilise afterwards.

With the same assumptions I show below the effect of 10 simulated years of MDA, distributed annually in SAC with a coverage of 75% and an efficacy of 80%.



Assuming NO density-dependency for egg production.

(Polman, de Vlas (2000))

The particles in the reservoir increase linearly without an upper bound. Without any limiting mechanisms it can reach implausible values going to +∞, even though we consider aging, births and deaths of individuals.



**PRIORITIES / DISCUSSION POINTS:**

1. **Limiting mechanisms.** We need limiting mechanisms that can help to stabilise the number of particles in the reservoir, in case we do not assume density-dependency in egg production. Those can be explored:
   1. Death of individuals due to high burden of worms
   2. Saturating effects in the reservoir due to saturation of resources or seasonality

**NEXT STEPS:**

1. Role of intermediate host.
2. Probability of worms’ reproduction (now we are assuming that all worm pairs reproduce).
3. Death of worms: individual lifespans can be generated.