# Total eradication of mosquitoes: potential impact on the environment

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Photographs: © G. Brehm

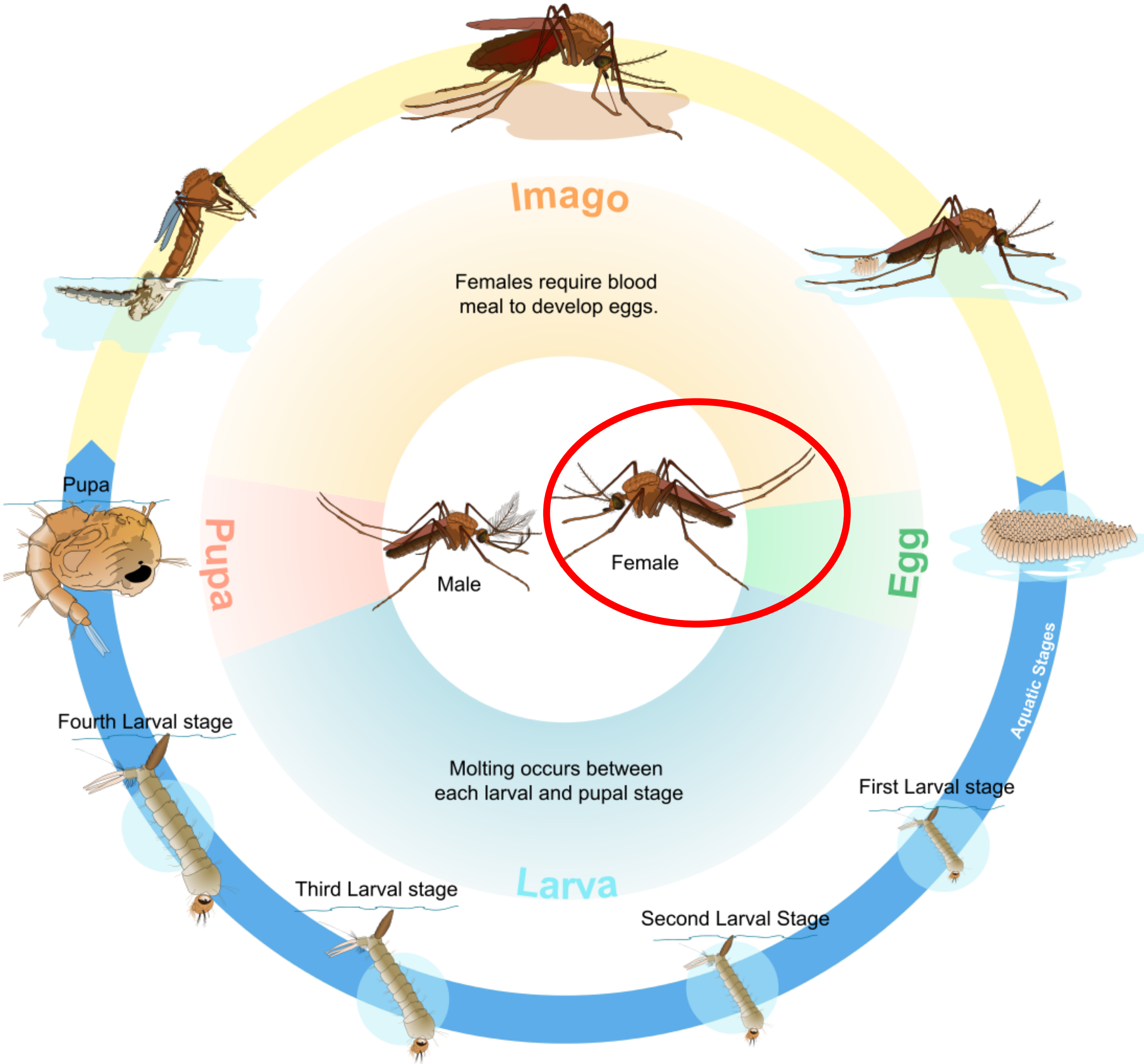
- Life cycle of a mosquito
- Functions and roles of mosquitoes in ecosystems
- Conventional mosquito control – effects on ecosystems
- Perspective: CRISPR/CAS-based mosquito control

*Anopheles albimanus*

http://www.public-domain-image.com

*Anopheles stephensi*

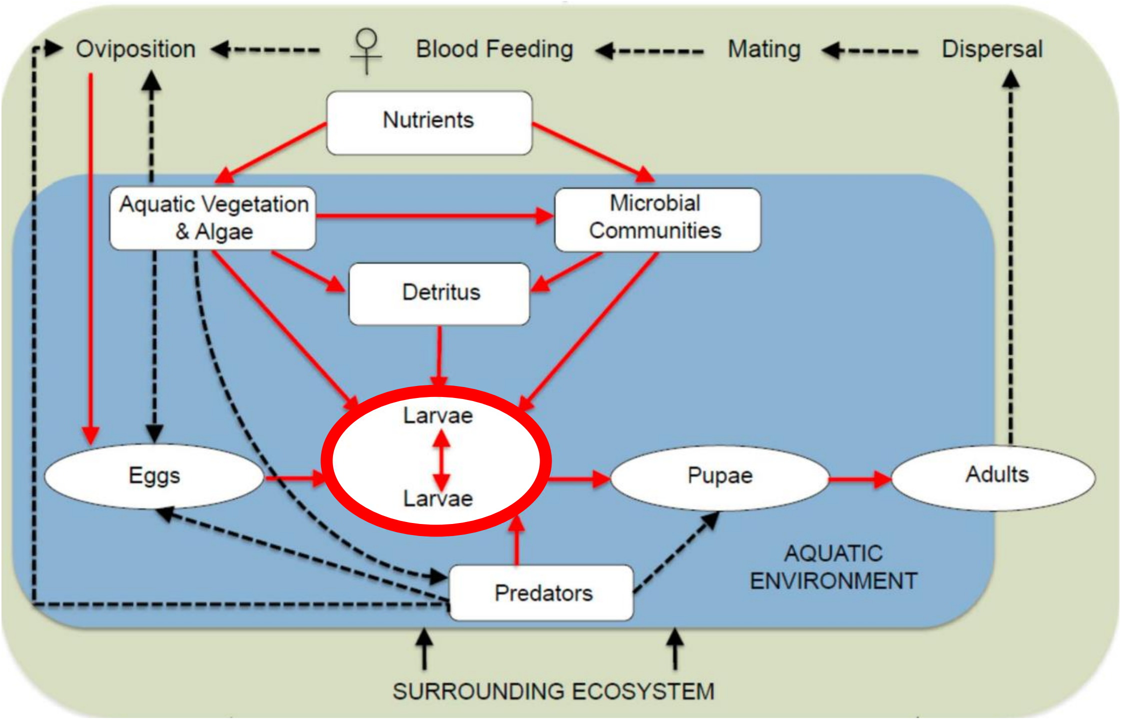
# Generalized life cycle of Culicidae




https://upload.wikimedia.org/wikipedia/commons/thumb/2/20/Culex_mosquito_life_cycle_en.svg

# Trophic interactions of mosquitoes – *Larval stages*

| **Filter feeders** | **Predators** |
|---|---|
| Collect micro-organisms (bacteria, unicellular algae) and detritus | Catch other (small-sized) aquatic invertebrates |
| Species of medical relevance, e.g. *Anopheles, Aedes, Culex* ... | Mostly species without medical relevance |




http://www.intechopen.com/source/html/43671/media/1.png

Mosquito larvae of health-relevant species:

- may develop in water bodies of <u>any</u> size
- <u>*r*-selection</u>: larval density regulated by resource availability
  → ***bottom-up control*** drives population dynamics
- important in ***aquatic food webs***
  → prey organisms for fish, birds, invertebrates, ...
- <u>often</u>: ***multiple*** syntopic Culicid species, with (slightly) different niche requirements → make up a ***community***

# Trophic interactions of mosquitoes – *Adult stage*



## Adult stages of health-relevant species:

- both sexes – visit ***flowers*** for ***nectar***, thereby ***pollinate*** plants
- some plants – even ± depend on mosquito pollination
- only ***females*** – attack animal hosts for ***blood meals***
- important ***in terrestrial food webs*** → prey for birds, spiders, etc.

# Conventional strategies of mosquito control
# – some ecological consequences –

## I Eliminate habitats ↔ *Destruction of breeding sites*

- Standard: minute anthropogenic water bodies in urban environments
- Otherwise (e.g. drainage at landscape scales):
  massive ***loss of biodiversity*** and multiple environmental resources

## II Implement top-down control ↔ *"Classical" biocontrol*

- Feasible at small scales, high (& continuous) work load (e.g. mosquito fish)
  → *r*-selected targets
- "Environmentally friendly" ↔ risk of ***bio-invasions***

## III Increase mortality ↔ *Application of insecticides*

- Feasible and successful, but <u>not sustainable</u>
- High environmental costs and risks: ***non-target species***, alters food webs,
  evolution of ***resistance***, ***eco-toxicological*** effects ...

Common environmental problem of all three approaches:

- Completely ***unselective***
- Impair ***non-target species*** (and their ecosystem functions and services)
- Put ***entire food-webs*** and ecosystems at risk

Selective methods would be most desirable!!

This is where CRISPR/CAS methodology might come in

# Important features of mosquito eradication through *gene drive*

- ***High specificity*** – mutant genes unlikely to jump across species boundaries (as long as hybridization is rare)
- ***Quick spread*** within populations and across activity range of adults
- "*Knock-out*" of ***individual vector species*** seems feasible

# Selective eradication – possible ecological consequences

## Interruption of ***unique links*** in ecological networks

- Examples: plant loses specific pollinator; bird or fish loses major prey species
- Probability: ***low*** – other mosquito species in community may take over function(s)
- Risk assessment: check for ***specific biotic links*** – in every target region

## Shift in ***abundance relationships*** among mosquito species

- Example: mosquito *XY* → abundant after *Anopheles gambiae* eradication
- Probability: ***high*** – turnover among species with similar ecosystem functions → ***novel "pests"*** fill vacant niche space ↔ ***competitive release***
- Risk assessment: check for ***candidate species*** – in every target region

Shift in ***structure*** of ***entire food webs***

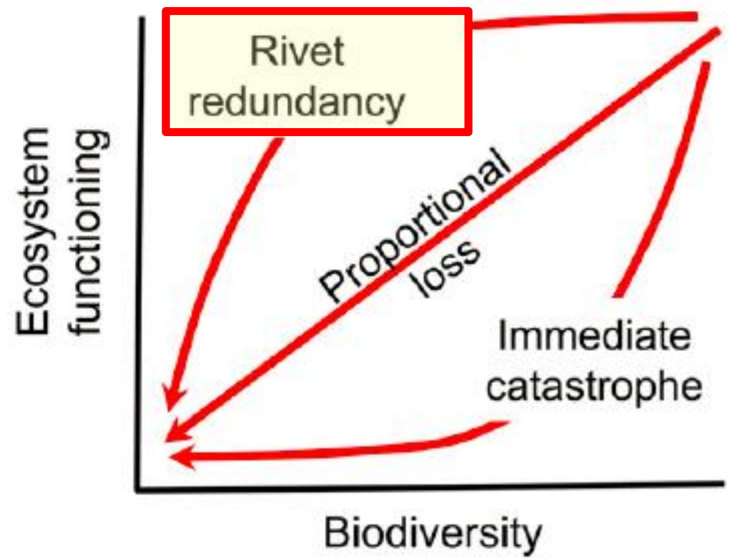
- Example: *Anopheles* eradication → other arthropods take over functions in breeding waters → repercussions at higher trophic levels → novel communities
- Probability: ***????*** – currently unpredictable
- Risk assessment: check for ***candidate species*** – in every target region

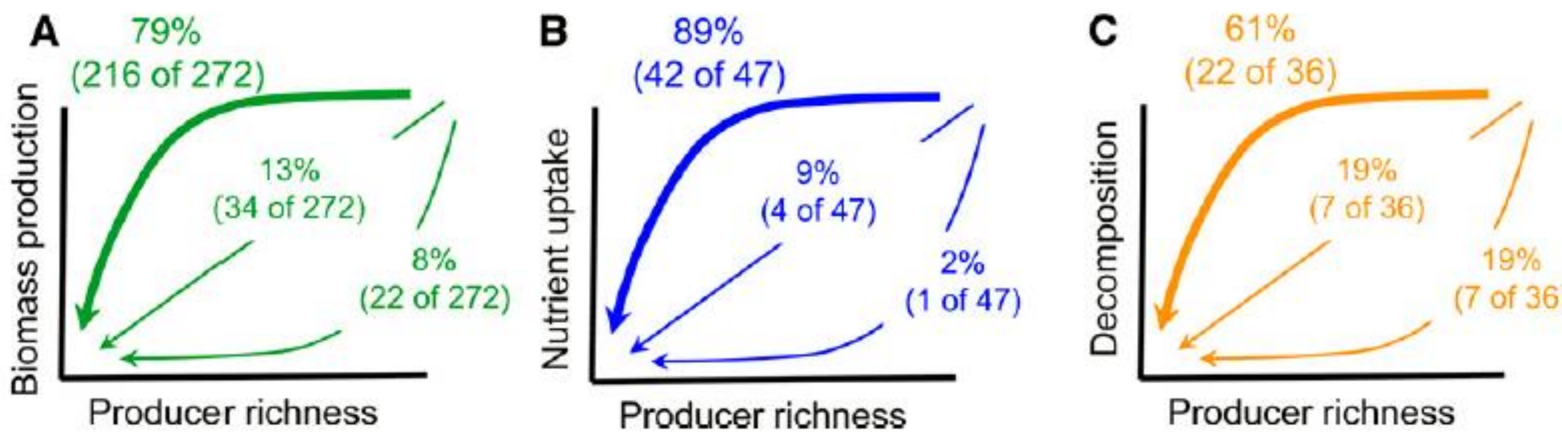
Modified genes manage to jump across species borders

- Example: gene flow between (closely related) mosquito species
- Probability: ***????*** – currently unpredictable
- Risk assessment: check for incidence of ***introgression***

Human population (further) increases in target regions

# BioDiversity and Ecosystem Functioning – the BDEF debate




BJ Cardinale et al. (2011) *American Journal of Botany*, ***98*** (3): 572-592.

- Biodiversity ***DOES MATTER*** – ecosystem functioning & resilience
  $\rightarrow$ ***functional complementarity***
- Also ***"rare"*** species count
- Usually – loss of single species compensated by others
  $\leftrightarrow$ ***functional redundancy***
- BUT: ***keystone species*** !!??
- Dilemma: ***hardly predictable*** – especially in diverse ecosystems or at larger time scales

# Some (subjective) tentative conclusions

- Ecological risks from eradication by gene drive – *lower* than detrimental effects of *conventional mosquito control*
- *Predicting* effects of removal of single species – *impossible*
- *Functional redundancy* of species – ecosystems tolerate (a few) eradicated species, UNLESS these are *keystone species*
- Creating a *vacant niche* – community responses (via competitive release) very likely
- Community shifts may *cascade* through *other trophic levels*
- *Risk assessment research* mandatory

**Thank you ...**