Spatial Dynamics of Insecticide Resistance in Mosquitoes O. Richter Institute of Geoecology, Universiy of Technology Braunschweig, Germany

Motivation: Resistance is known to affect all major malaria vector species and all four recommended classes of insecticides. Since 2010, a total of 61 countries have reported resistance to at least one class of insecticide.

COMSOL Multiphysics[®] environment



Governing equations: For the life cycle of species comprising mobile and immobile stages, systems of partial and ordinary differential equations for the winged and aquatic phase respectively are set up.

$$\begin{array}{l} \frac{\partial A}{\partial t} = e(\text{Temp, water bodies, insecticide,...}) \\ \frac{\partial A}{\partial t} = \phi(e)M - \gamma(e)A - \mu_A(e)A(1 + \alpha A) \\ \text{oviposition hatching nonlinear mortality rate} \end{array}$$

Aquatic phase
$$\begin{array}{l} \frac{\partial M}{\partial t} = \nabla \cdot (D(e)\nabla M - \vec{v}M) + r\gamma(e)A - \mu_M(e)M \\ \text{random dispersal vectored dispersal hatching mortality rate} \end{array}$$

Winged phase

Figure 1. Single population with aquatic and winged phases

Resistance is conferred by metabolic or target site

Figure 4. Large scale dispersion: Combining COMSOL[®] and geographical information





Figure 5: Vectored dispersal is modeled by a "Chemotaxis" approach with density of water bodies as attractant

Results:

changes in mosquitoes involving polygenic or monogenic inheritance respectively causing a shift of ED50 values of dose response curves.

Survival probability



For each biotype "i", the model integrates the dynamics of the aquatic phase Ai and of the winged phase Mi and their genetic interactions via the hereditary matrices Wi.



Figure 6: Sensitive biotypes (left) cannot cross a spray barrier, resistant biotypes (right) break through the barrier.



Figure 2. Shift of dose response curves



Figure 3: System of n genetically coupled biotypes

Figure 7: Resistant biotypes only emerge under spraying (left). Otherwise, fitness penalty keeps them at low levels (right). Biotypes 1-9 ordered by increasing resistance.

Future work: The model will be applied to the assessment of control schemes involving allocation of set aside areas and genetic control.

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