Introduction
Malaria kills almost one million people worldwide every year. The disease is transmitted to humans by the bites of infected female Anopheles mosquitoes. Global efforts to tackle malaria have gained unprecedented momentum after a paradigm shift from malaria control to malaria eradication following the ‘Gates Malaria Forum’ held in Seattle in October 2007. However, in order to move towards the ambitious goal of eliminating and eventually eradicating malaria, existing tools must be improved and new tools developed. Such tools need to be cost-effective, scalable, and compatible with prevailing health and social systems.

The most important and widely-applied malaria control tools available today comprise artemisinin-based combination therapies for treatment, intermittent preventive treatment in pregnancy and infants, rapid and reliable diagnosis of malaria, and vector control by insecticide-treated bednets as well as indoor residual spraying. Complementary vector control measures that can play an important role in specific settings are environmental management (reduction of standing water bodies, for example by drainage) and larviciding (application of biological or synthetic insecticides in standing water bodies in order to kill mosquito larvae).

Anopheles mosquitoes generally breed in temporary sun-lit small ponds, pools and puddles, and in more permanent habitats such as marshes. Anopheles mosquitoes prefer fresh water habitats, although they can also breed in polluted or saline waters. Examples for important breeding sites are shallow open sun-lit pools such as borrow pits, drains, car tracks, hoofprints around ponds and water holes, and pools left as overflowing rivers and streams recede, and rainwater collecting in natural depressions.

Larviciding can be a useful complementary strategy to the main malaria control tools (Castro et al., 2004; Chaki et al., 2009; Fillinger et al., 2008; Geissbühler et al., 2009), particularly in urban areas, because breeding habitats are usually fewer compared to rural areas and can be accessed.

Anopheles mosquito breeding site in Dar es Salaam
Controlling mosquito larvae in Dar es Salaam

The Dar es Salaam Urban Malaria Control Programme (UMCP) was initiated by the Dar es Salaam City Council in collaboration with Ifakara Health Institute and a consortium of overseas partner institutions as a pilot program to develop sustainable and affordable systems for larval control as part of routine municipal services (Castro et al., 2004; Mukabana et al., 2006). Specifically, the UMCP implements the regular application of biological larvicides through community-based but vertically managed delivery systems. The current phase of the UMCP was launched in March 2004 (Fillinger et al., 2008; Geissbühler et al., 2009).

During the first year of the UMCP, new larval and adult mosquito surveillance systems were set up using practical procedures that rely on minimal technology. Staff were recruited and trained, and management systems were designed. After one year of baseline data collection, operational larviciding with Bacillus thuringiensis var. israelensis commenced in March 2006 in three wards. A year later, the intervention area was expanded to nine wards.

Since 2008, 15 urban wards of Dar es Salaam have been included in the UMCP larviciding scheme, covering a population of approximately 612,000 residents and an area of 56 km². Responsibility for larviciding has been delegated to modestly-paid community members, known as Community-Owned Resource Persons (CORPs). In 2009, a new mobile-phone based surveillance system was introduced which replaced the
former (and slower) paper-based system. The new system allows programme managers to access information and optimize control strategies in a manner that is timely enough to account for the short reproductive cycle (ca. 1 week) of Anopheles gambiae mosquitoes, the primary malaria vectors.

A participatory mapping and monitoring approach has been developed and introduced. This approach comprises community-based development of sketch maps of the target areas, and verification of the sketch maps using laminated aerial photographs in the field, which are then digitized and analyzed using Geographical Information Systems (GIS). This mapping approach has enabled gap-free coverage of intervention areas with mosquito larval control, and more equal distribution of the workload of field staff (Dongus et al. 2007).

There is a clear downward trend in malaria infection prevalence in people, and their risk of exposure based on measured mosquito densities and infection rates in Dar es Salaam between 2005 and 2008. This is partly due to larviciding, which started in 2006. However, other malaria control interventions (such as use of insecticide-treated bednets, introduction of artemisinin-based combination therapies and screening of houses by self-initiative) have contributed to the observed reduction in malaria infection prevalence.

The encouraging results in Dar es Salaam are paralleled by similar findings from experimental programmes in the highlands of Kenya (Fillinger 2009) and Eritrea (Shililu 2007), and historical successes in the Zambian copper
Larval control may be most useful for malaria control in areas that have limited, focal distribution of surface water (because of topographic relief, aridity or urbanization), high human populations density, and strong governance and institutional capacity (Killeen 2002, Killeen 2006).

**Challenges and prospects**

**Complementary intervention:** Larviciding should be seen as a complementary vector control tool *in addition* to insecticide-treated bednets and indoor residual spraying.

**Access to breeding sites:** While many breeding sites in urban areas are easy to access, some residents don’t allow larviciding teams to enter their compounds, leaving some mosquito breeding sites left untreated.

**Community perception:** 95% of mosquitoes found in Dar es Salaam are not *Anopheles* mosquitoes but still cause major nuisance. To sustain community trust in the effectiveness of the intervention, larviciding should aim to reduce the numbers of all mosquitoes.

**Short treatment intervals:** The primary malaria-transmitting mosquitoes develop from egg to adult within a week or less. Because the currently-available larvicides only remain effective for around seven days, weekly re-treatment of breeding habitats is required.

**Quality assurance:** Larviciding teams need close supervision in order to sustain optimal performance.

**Monitoring:** High-resolution, fine scale spatial and temporal monitoring of adult mosquito density is needed in order to detect coverage gaps.

**Sustainability:** In 2010, the Government of Tanzania took over the funding of the programme from international donors. Prior to handover, changes in administrative structure and field procedures achieved a halving of implementation cost – from less than $1.00 to less than $0.50 per person protected per year (Worrall 2007).

**Measuring relative impact:** In this study area, many different malaria control interventions have been implemented concurrently. This makes it difficult to isolate the impact contribution of individual strategies.

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**References**


