Larval Source Management (LSM) in Dar es Salaam, Tanzania

A prominent example of LSM in urban sub-Saharan Africa is the Urban Malaria Control Program (UMCP), Dar es Salaam, initiated by the City Council in collaboration with Ifakara Health Institute and overseas academic institutions [1-2]. In 2004, mosquito surveillance systems were established and after one year of intensive baseline data collection (2005-2006), operational larviciding with Bacillus thuringiensis var. israelensis commenced in three wards during March 2006 [2-3]. In 2007 the intervention was expanded to nine urban wards. Since 2008, 15 wards comprising 56 km² and 614,000 city residents have been covered.

Background

• **Site characteristics:** Dar es Salaam is a coastal city with a population of about 2.5m and a total administrative area of 1,393km². LSM was introduced into three municipalities (Kinondoni, Tembeke and Ilala) which are divided into wards and sub-divided into 360 neighbourhoods (mitaa) [2-3].

• **Climate:** Hot and humid, with long rains from March to May and short rains in November-December. Average annual rainfall is 1115mm [4].

• **Primary and secondary vectors:** The primary vectors are Anopheles gambiae and An. funestus. An. merus is a secondary vector.

• **Main types of breeding site:** An. gambiae largely breeds in clean freshwater, but can be found in nearly every type of water, including polluted water bodies; An. funestus breeds in permanent water bodies such as inland marshes [4]. Over 70% of larval habitats in the city are man-made, of which many are drains [2].

• **Malaria transmission:** Transmission is low and perennial and 90% of cases are Plasmodium falciparum [4]. Outdoor biting is common, possibly because mosquitoes find it difficult to enter houses with closely fitted doors and windows, as well as the high bed net coverage. Urbanisation has generally reduced breeding sites [4] however shanty towns at the periphery of the city are characterised by open sand and borrow pits which are ideal breeding sites [4].

The larval source management program

• **Structure of the control program:** The Urban Malaria Control Program is fully integrated into the Dar es Salaam City Council administrative system and operates at five administrative levels: the City Council, municipalities, wards, neighbourhoods and over 3000 Ten Cell Units (TCUs) [5]. Community-Owned Resource Persons (CORPS), modestly paid members of the community, are responsible for routine mosquito control and surveillance and report to Ward Offices. All standard operating procedures and forms are available online [2].

• **Baseline mapping and data collection:** Baseline mapping of all targeted areas was conducted in 2004. Each CORP was then allocated a small area (approximately 0.6km²), in which they were responsible for larval surveillance. All larval habitats were mapped, classified into one of twelve categories and checked once a week for the presence of larvae using up to 10 dips with a 350ml dipper [6]. Anopheles and culicines were differentiated and larvae classified as early or late instar. In the first year (2004), over 65,000 potential Anopheles habitats were surveyed by 90 CORPs every week [2].

• **Larviciding:** Following one year of baseline data collection by the CORPs, one ward per municipality (three in total with a combined area of 17km² and 128,000 residents) was selected for intensive surveillance and larval control, based on staff competence. One non-intervention ‘comparison’ ward from each of the three municipalities was selected for intensive surveillance, using the same criteria as the intervention wards. Surveillance was also continued and improved in remaining wards [2]. Larviciding commenced in March 2006 with Bacillus thuringiensis var. israelensis strain AM65-52 (Bti; VectoBac®, Valant BioSciences Corporation (VBC), USA) and Bacillus sphaericus strain 2362 (Bs; VectoLex®, VBC), applied as two formulations: (1) water-dispersible granules
suspended in water and applied using Solo® 475 knapsack sprayers and (2) corn granules applied by hand [2]. The program targets culicine mosquitoes in addition to anophelines to reduce nuisance biting and maintain community support [2]. ‘Open’ habitats exposed to sunlight are treated weekly by Mosquito Control CORPS, and shaded ‘closed’ habitats (e.g. pit latrines) are treated every three months. Insecticide stocks are managed at a central storage location [2]. Daily insecticide use is recorded by each ward supervisor and monitored at city-level. In May 2007 the program was expanded to nine wards and then to 15 wards in March 2008 [5].

- **Ongoing larval surveillance**: During the early years of the program, 90 Larval Surveillance CORPs were deployed at any given time, each responsible for surveying open habitats in assigned Ten Cell Units (TCUs, the smallest administrative area in the city) down to plot level the day after treatment and reporting to the Ward Office. A plot here refers to a housing compound or small area of land. Municipal Mosquito Control Inspectors (MMCIs) independently validated the work of the CORPs via twice weekly spot checks [2-3]. Larval surveillance data were collated by Ward Supervisors and forwarded to the Municipal Mosquito Control Coordinator (MMCC), who submitted monthly reports to the City Mosquito Control Coordinator (CMCC). Recently this system was updated and larval surveillance is now conducted directly by Ward Supervisors, who visit six TCUs per week selected by the program managers and six further TCUs chosen at their own discretion. Daily reports are uploaded using mobile phones to a web-based server and made available through a password protected link. It is envisaged that this will improve access to data and dramatically reduce operational costs.

- **Adult mosquito surveillance**: Initially, Mbita-design bed net traps, CDC light traps and pyrethrum spray catch were shown to be ineffective at catching *Anopheles* species, possibly because indoor biting is rare. Therefore human landing catches (HLC) were used as a pilot method, with 67 CORPs surveying 268 locations monthly. However this was costly, difficult to sustain and exposed workers to potentially infectious mosquito bites [2]. Therefore an intensive community-based system for routine surveillance using the Ifakara Tent Trap (ITT-C) was developed and implemented in the 15 UMCP wards in February 2009 and 16 adjacent non-intervention wards in October 2009, covering an area of 160km² and 2.65 million residents [7]. One person per ward was recruited to conduct monthly night-long surveys in 20 locations per ward and modestly remunerated with US$2.70 (2010) per trapping night. Caught mosquitoes are identified in a central laboratory to the genus level and anophelines identified to species level. *Anopheles gambiae* mosquitoes are identified to sibling species level by PCR. ELISA is used to determine whether mosquitoes are infected with sporozoites [7]. ITT-C has been evaluated by two quality assurance (QA) teams who in turn conducted ITT-C and HLC at randomly selected locations. This showed that ITT-C had lower sensitivity than HLC, however was cost-effective and could predict the odds of human parasite infection [7].

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- **Other malaria control interventions**: As part of the Malaria Control Strategic Plan 2008-2013, Long Lasting Insecticidal Nets (LLINs) are distributed through a voucher scheme. 70% households owned at least one ITN in 2007-2008 [8] and 62% prior to LLIN distribution in 2010 [9].

**Impact**

**Clinical outcomes**: malaria infection prevalence in children aged 0-5 years declined between baseline data collection in 2004-2006 and after the introduction of larviciding in 2006-2007 (Odds...
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Ratio = 0.284, 95%CI 0.101-0.801; adjusted for location, survey round, LLIN use and repellent use; Fig. 3) [3]. It is difficult to directly attribute the decline in malaria to larviciding. Certainly, there is little evidence that larviciding had any impact on the prevalence of malaria infection among all age groups [3]. Figure 3 also indicates an interesting decline in parasite prevalence in non-intervention wards. However, post-intervention, parasite prevalence is significantly lower in intervention wards in children aged 0-5 years (Fig. 3).

- **Entomological outcomes**: malaria transmission declined between April 2005 and March 2007 (crude relative annual Entomological Inoculation Rate = 0.683, 95%CI 0.491-0.952) alongside a significant reduction in malaria vector abundance and biting rates [3].

- **Effect of other interventions**: Other interventions such as house screening, LLINs and the introduction of artemisinin combination therapies may have also contributed to the decline in malaria [5].

**Challenges**

- Some residents do not allow larviciding teams to access habitats in their compounds [3, 5].
- Weekly treatment of breeding sites is required because the larvicides used have low residual efficacy [5].
- All mosquito species must be targeted to reduce nuisance biting and maintain community support.
- Close supervision of larviciding teams and continuous monitoring is required [5].
- Achieving sustainability is an ongoing challenge. International donors handed funding of the program to the Tanzanian Government in 2010. Before this, implementation costs had to be halved from <$1.00 to <$0.50 per person per year [5, 12].
- Concurrent malaria control interventions complicate the measurement of the impact of LSM [5].

**References**


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