“Before DDT, Mraliologists were trained as problem solvers....

.....after DDT, Mraliologists were trained as solution implementers”

- José Najera
Solving the Problem

- Insecticide Resistance
- LLIN continuous distribution
- Durability
- LLIN/IRS and Durable Wall Lining
- IRS capacity
- Entomological monitoring & IVM
- Larval Source Management
- Forest malaria/outdoor transmission
Monitoring and Mitigation of Insecticide Resistance

Implement:

- Basic entomological monitoring package
- Resistance monitoring
- Insecticide selection
- Long-term management: IVM
An gambiae ss Senegal

green is good, red is bad

<table>
<thead>
<tr>
<th></th>
<th>Deltaméthrine</th>
<th>Lambdacyhalothrine</th>
<th>Perméthrine</th>
<th>DDT</th>
<th>Fénitrothion</th>
<th>Bendiocarb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dussouye</td>
<td>95</td>
<td>94</td>
<td>100</td>
<td>90</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>Tambacounda</td>
<td>96</td>
<td>85</td>
<td>56</td>
<td>99</td>
<td>83</td>
<td>48</td>
</tr>
<tr>
<td>Kédougou</td>
<td>89</td>
<td>69</td>
<td>16</td>
<td>48</td>
<td>64</td>
<td>11</td>
</tr>
<tr>
<td>Ndoffane</td>
<td>95</td>
<td>100</td>
<td>67</td>
<td>95</td>
<td>73</td>
<td>39</td>
</tr>
<tr>
<td>Vélingara</td>
<td>92</td>
<td>82</td>
<td>58</td>
<td>80</td>
<td>90</td>
<td>88</td>
</tr>
<tr>
<td>Dioffior</td>
<td>100</td>
<td>87</td>
<td>91</td>
<td>100</td>
<td>92</td>
<td>100</td>
</tr>
<tr>
<td>Thiès</td>
<td>100</td>
<td>84</td>
<td>73</td>
<td>48</td>
<td>66</td>
<td>18</td>
</tr>
<tr>
<td>Guédiawaye</td>
<td>97</td>
<td>89</td>
<td>96</td>
<td>8</td>
<td>82</td>
<td>12</td>
</tr>
<tr>
<td>Linguère</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>91</td>
<td>98</td>
</tr>
<tr>
<td>Richard Toll</td>
<td>99</td>
<td>38</td>
<td>95</td>
<td>42</td>
<td>100</td>
<td>7</td>
</tr>
<tr>
<td>Podor</td>
<td>100</td>
<td>100</td>
<td>98</td>
<td>99</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>Dakar Centre</td>
<td>43</td>
<td>12</td>
<td>8</td>
<td>6</td>
<td>98</td>
<td>97</td>
</tr>
</tbody>
</table>
Guidelines for rotation and mosaics

Insecticide Mode of Action Classification: A Key to Effective Insecticide Resistance Management in Mosquitoes

Insecticides used to control adult mosquitoes

- **Insecticides disrupting moulting and metamorphosis**
  - Mosquito larvae moult several times during their development and undergo complete metamorphosis when becoming adults.
  - Group 7: Juvenile hormone mimics
    - JH analogues (Group 7A) and Pyriproxyfen (Group 7C) interfere with the hormonal regulation of development.
  - Group 15: Inhibitors of chitin synthesis
    - Benzoylureas: inhibit the production of chitin structures within the insect.
  - Group 17: Moulting disruptor, Dipetane
    - Cymazine, disrupts successful larval development

Insecticides acting on the nervous system

- **Insecticides used to control mosquito larvae**
- **Microbial disruptors of insect midgut membranes**
  - Derived from bacteria, these toxins need to be ingested
  - Group 11: Microbial disruptors of insect midgut membranes
    - Bacillus thuringiensis var. israelensis, Bti, Bacillus sphaericus, Bs

Insecticides acting on the nervous system

- Group 1: Acetylcholinesterase (AChE) inhibitors
  - Carbamates (Group 1A) and Organophosphates (Group 1B), act as AChE inhibitors at nerve synapse, resulting in hyperactivity in the nervous system.
- Group 3: Sodium channel modulators
  - Pyrethroids and Pyrethrins (Group 3A) and DDT (Group 3B), rapidly interfere with the propagation of action potential along nerves, leading to hyperactivity and nerve block.

Insecticide classes for mosquito control

<table>
<thead>
<tr>
<th>Group</th>
<th>Mode of Action</th>
<th>Chemical sub-group or exemplifying active ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Acetylcholinesterase inhibitor</td>
<td>Carbamates</td>
</tr>
<tr>
<td>1B</td>
<td></td>
<td>Organophosphates</td>
</tr>
<tr>
<td>3A &amp; 3B</td>
<td>Sodium channel modulators</td>
<td>Pyrethroids and pyrethrins, DDT</td>
</tr>
<tr>
<td>5</td>
<td>Neuronal acetylcholine receptor agonists</td>
<td>Spinosyns</td>
</tr>
<tr>
<td>7A</td>
<td>Juvenile hormone mimics</td>
<td></td>
</tr>
<tr>
<td>7C</td>
<td></td>
<td>Juvenile hormone analogues</td>
</tr>
<tr>
<td>11</td>
<td>Microbial disruptors of insect midgut membranes</td>
<td>Bacillus thuringiensis var. israelensis</td>
</tr>
<tr>
<td>15</td>
<td>Inhibitors of chitin biosynthesis</td>
<td>Bacillus sphaericus</td>
</tr>
<tr>
<td>17</td>
<td>Moulting disruptor, Dipetane</td>
<td>Cymazine</td>
</tr>
</tbody>
</table>

Further reading

- WHO (2008): Pesticides and their applications
  - WHO/CCCP/WHOPES/GCD
  - PP 6th edition, 114pp
  - www.who.int/whopes/gcd
- Prevention and management of insecticide resistance in vectors and pests of public health importance
  - www.irs碹lnfo.org

www.Irac-online.org
<table>
<thead>
<tr>
<th>Chemical class</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Cost/sachet (200-250 sq m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroid</td>
<td>Low toxicity</td>
<td>Resistance</td>
<td>$3.60 to $5</td>
</tr>
<tr>
<td></td>
<td>Low Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 7 months duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbamates</td>
<td>Medium tox profile</td>
<td>High cost</td>
<td>$13</td>
</tr>
<tr>
<td></td>
<td>It works</td>
<td>&lt; 4 month duration</td>
<td></td>
</tr>
<tr>
<td>Organo-phosphates</td>
<td>It works</td>
<td>Toxicity problems</td>
<td>$12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher Costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variable duration</td>
<td></td>
</tr>
<tr>
<td>Organochlorine (DDT)</td>
<td>Low cost</td>
<td>Management costs</td>
<td>$4 to $6.70</td>
</tr>
<tr>
<td></td>
<td>&gt; 7 months duration</td>
<td>Resistance</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supply</td>
<td></td>
</tr>
</tbody>
</table>
Decay and Durability

IRS Decay, Various Partners

LLIN Physical durability protocols (WHO)

LATH residual insecticide test (Photos: J. Hemingway)

X-ray fluorometer - deltamethrin in PermaNets (Photo: S. Smith)
LLINs

Since 2008:
>300m by all partners

- Pyrethroid insecticides;
- Cost ~ $6 each;
  Plus $1-2 shipping, delivery, BCC
Deployment “best practices”

Mass Campaign
(RBM-AMP)

Continuous
(RBM- VCWG)

- Clinics, EPI services
- Targeted subsidies (vouchers)
- Facilitate commercial sector

Communications
- for appropriate use
Optimizing Vector Control: LLINs and IRS

Co-deployment:
Impact and cost-benefit

Sustain success:
transition for long-term control
New product categories:
Durable Wall Linings

Photo: J. Gimnig
Now >27m persons protected, also focus on Pesticide Management
IRS Capacity Building and Health Systems Strengthening

Environmental Assessment

Mapping, Targeting and Quantification
- GIS, GPS
- Evaluation
  - Epidemiological
  - Entomological
  - Environmental

Pesticide Selection and Procurement
- Micro-Planning
  - Timing and Program of spraying

Action
- Supervision, information management, environmental compliance

Training
- Spray teams, supervisors

Organization logistics
- Teams, transport, supplies, systems
IRS Optimization:

Targeting

Quality
Facilitate deployment of new products

- **New formulations**
  - (Primiphos-methyl CS)

- **New active ingredients**
  - (Chlorfenapyr)
IVM: Five Key Elements:

- Advocacy, social mobilization and legislation
- Cross sector collaboration
- Integrated approach
- Evidence-based decision-making
- Capacity-building
Building Capacity

Working with WHO, RBM African Institutions and the private sector to build technical capacity for implementing, monitoring and sustaining vector control.
Inventory of 29 Research and Training Institutions for Entomology and Vector Control in 18 Countries

Red = malaria endemic areas
Role of larval control
Where does it work? Where’s the proof?

Semi-permanent sites – possible?
Temporary breeding sites - difficult
Artemisinin resistance in the Mekong

Adam Nadel/Malaria Consortium. With Permission
Parasite Clearance Time
Pailin 2007

Dondorp, NEJM, 2009
2008-2009 HIGHLIGHTS

- Decreasing efficacy of ACTs and AS7 in some countries
  - initially along Thai-Cambodia border (Trat and Pailin)
  - now documented in other areas by in vivo studies

- Prolonged parasite clearance time [>30% Day 3 parasite (+)]

1. Cambodia (western border)
   Pailin (AS+M, AS7, DHA-PIP)
   Veal Veng –ditto-
2. Thailand
   Trat (AS+M)
   Tak
   Ranong

New areas
3. Myanmar
   Kawthaung (AS+M, AS+AMO, AL)
4. China
   - Dehong, Yunnan - AS7
5. Viet Nam
   - Binh Phuoc - AS7

Critical areas in the Mekong network
A Cryptic Subgroup of Anopheles gambiae Is Highly Susceptible to Human Malaria Parasites
Michelle M. Riehle, et al

ITNs and IRS Programs can Change Vector Populations & Behaviour

Shifting A. gambiae to An. arabiensis
Hammock Nets

- Magris Yanomami Venezuela 2007 (84%)
- Thang Vietnam 2009 Prev 16.7-11.7%
- Sochantha Cambodia (in press) *An. dirus* (46%)
Treated Clothing

Individual Dynamic Absorption Kit (IDA)           NSN 6840-01-345-0237

Kit Components
- Vials of permethrin
- Ziploc Bags
- Ties
- Protective gloves
Can we pull it together?

- Vector mapping and bionomics
- Remote sensing for targeting
- Repellents
- Treated Hammocks / Nets
- Treated clothing
- Insecticide Treated Plastic Sheeting
“Never let a serious crisis go to waste”
- Rahm Emanuel

- Resistance
- LLIN
- Combinations
- New products
- Capacity
- Larvae
- Outdoor transmission