Vector Control Technical Expert Group
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Capacity Building in Entomology and Vector Control

Contents

Executive Summary ............................................................................................................................................. 2
Key recommendations ......................................................................................................................................... 4
Introduction ....................................................................................................................................................... 6
1. Entomological surveillance .......................................................................................................................... 8
2. Infrastructure capacity ................................................................................................................................. 10
3. Opportunities for expanded information management in the planning, implementation and evaluation of vector control ........................................................................................................................................ 11
4. Revision of current curricula in training institutions to meet the needs of control programmes .............. 12
   Examples of capacity strengthening for national malaria control programmes ........................................ 14
5. Institutional arrangements - vector control structures and services ......................................................... 15
6. Career opportunities for public health entomologists ............................................................................... 16
7. Donor coordination for capacity building ................................................................................................. 17
8. Conclusions and recommendations .......................................................................................................... 18
   Key recommendations ................................................................................................................................... 18
9. References ..................................................................................................................................................... 20
Executive Summary

Malaria control is at a critical juncture. We cannot achieve the goal of malaria elimination in many settings, nor even sustain our current gains without adapting to the changing threats and opportunities to controlling transmission. Progress in global malaria control over the past decade was largely gained through investments in vector control, especially insecticide treated mosquito nets (ITNs) and indoor residual spraying (IRS). In order to sustain and build further on these gains, there is a need to improve the efficiency of malaria vector control, including through better targeting of interventions, and effectively managing anopheline resistance to insecticides. These challenges can only be met by national staff with the training, support and career structures required to be able to effectively plan, monitor, evaluate and manage control programme efforts. Investment in human resources and the particular systems for public health entomology and vector control, while requiring initial investment, will ultimately save money, ensure the gains of the past decade are not lost, and enable us accelerate progress in the control and elimination of malaria.

In the past, WHO played a leading role in coordinating training in entomology and vector control, and in directly supporting implementation at the country level. Now, the landscape of global health has expanded to include other intergovernmental agencies, NGOs, the private sector and other partners who assume direct engagement with malaria endemic countries. The guidance and leadership of WHO nonetheless, continues to be crucial in these organizations’ partnerships. A number of these partners provide countries with financial resources for commodities and for vector control implementation. With such broad support, there is an urgent need to coordinate these resources in order to prioritize system strengthening through capacity building of ministry staff as well as relevant infrastructures for entomological surveillance and vector control.

This paper reviews capacity needs in malaria entomology and vector control within national health systems, focusing on the public health vector biologist cadre at both the national and subnational levels. This paper does not address entomological capacities at national universities and research institutes. The paper notes the need to expand and adapt entomology and vector control skills to include an epidemiological approach and to take better advantage of the revolution in information management and communication technology, but equally important to providing the right skills, is to ensure there are adequate career opportunities for trained entomologists in the national health system.
In summary, the paper notes the following:

- gaps, and opportunities, for strengthening capacities in routine entomological surveillance system for data collection, analysis and management, especially for monitoring insecticide resistance;
- opportunities for strengthening infrastructure for entomological laboratories and insectaries, including specific arrangements between NMCPs and national training and research institutions;
- opportunities to use information communication technology to more effectively collect and respond to epidemiological and entomological field data, and to the planning and implementation of vector control interventions;
- opportunities to improve curricula for both short and long-term training;
- establishment of career opportunities and structures with specified ranks within the ministry of health; and finally,
- opportunities for donor coordination and commitment for strengthening human resources and systems for national programmes that will be sustained long after the individual bilateral/multilateral support ends.
Key recommendations:

Countries to:

- ensure the presence of a functional intersectoral coordination mechanism with a sub-committee for capacity building responsible for developing a long-range strategic plan for building human resources and systems for public health entomology and vector control – including malaria;
- strengthen intersectoral collaboration with ministry of education, and with universities and in-service training programmes to ensure that public health entomology and vector control (including epidemiology and management) is included in curricula and educational activities;
- ensure that posts and career development and structures for entomology and vector control experts are established at national and subnational levels within ministries of health or other appropriate government structures;
- establish institutional arrangements among universities, training and research institutions and the national malaria control programme to support ongoing training and support for entomologists and vector control experts;
- conduct training needs assessment and curricula review for pre-service and in-service training, following relevant guidelines to be developed by WHO;
- ensure that there are sufficient resources for human and infrastructure capacity building factored into bi-lateral and multi-lateral projects/programmes and funding requests based on costed national strategic plans.

Partners to:

- ensure that all support to countries has a strong component of capacity building to include short and long-term training and mentoring as well support for the necessary entomological laboratory and insectary resources.
- ensure national “ownership” in all the technical and management activities;
- support national control programmes in clearly defining and implementing strategies to ensure that human and technical resources and systems are adequate to sustain and expand vector control efforts after partner support ends.
- Support global and regional efforts to revise curricula and make available training and on-going mentoring opportunities for national staff

WHO to:

- support countries in the mobilization of resources (human and financial) to implement capacity building activities;
facilitate the needs assessment for capacity building in public health entomology and vector control as part of a broader assessment of human resources for malaria control and elimination;

support relevant institutions and partners in revising and adapting appropriate curricula in entomology and vector control that address the needs of vector control programme staff at national and sub-national levels;

develop prototype strategic plans for capacity building and facilitate the development and dissemination of training materials on public health entomology and vector control;

support regional and global collaboration networks (including resource mobilization) for training, technical advice and continued mentoring for entomological monitoring and vector control operations; and

support a clearly defined advocacy strategy for public health entomology and vector control professionals, developed in collaboration with global, regional and national partners.
The last decade has witnessed a large expansion of investments for malaria vector control, mainly insecticides for indoor residual spraying (IRS) and long lasting insecticidal nets (LLINs) (1). It is estimated that in the last decade, these interventions have been primarily responsible for averting more than one million deaths due to malaria. Given the size of this investment for commodities and deployment, surprisingly little has been done to build the local infrastructure and skills needed to improve efficiency, monitor impact and sustain coverage with these vector control interventions. The development of an adequate cadre of individuals with entomological skills, as well as corresponding infrastructure to support them has been especially neglected. Insectaries and entomological laboratories are often run down or absent; collaboration between national malaria control prorammes and national universities and training institutions is often weak; and potential entomologists have few opportunities for training and generally poor prospects for employment once trained (2).

Global malaria vector control efforts are entering a new era, requiring improved entomological surveillance for more efficient and well-monitored vector control investments. Programmes must adapt to the emerging threat of insecticide resistance (3), to outdoor and early vector biting (4), and to shifting transmission patterns brought about through changing ecologies due to such factors as deforestation, agricultural and infrastructural development and urbanization. Programmes need more robust surveillance in order to ensure cost-effective use of interventions and resources as they move from control towards elimination. Entomological surveillance and a clear understanding of the local transmission ecology are critical for reducing receptivity and preventing the re-introduction of transmission where malaria has been eliminated (5). The contexts of malaria vector control and the role of the vector biologist are changing, reflecting innovation both in the tools for vector control and entomological monitoring, and also innovation in such areas as mobile technology, communications, information management, use of climate data and mapping for gaining greater efficiencies in surveillance and control.

Investment in entomological monitoring makes good business sense. Vector control, largely through LLINs and IRS, accounts for more than 60% of international and domestic funding for malaria control (1). There is evidence that in some cases, substantial resources may be going to waste through inappropriate or ineffective measures, such as using an insecticide for IRS where there is resistance, investing in larvicide where there is no evidence of impact, or deploying LLINs and IRS where there is very limited or no transmission (3 and 6). Especially in this era of increasing insecticide resistance and concerns for sustained funding, programmes...
need to build capacities to select and apply the right vector control methods at the right times and in the right places.

This document provides recommendations to countries, partners and to WHO for capacity building in entomology and vector control. The document will help countries identify areas for capacity needs and determine how this capacity can be built or strengthened, especially in the context of decentralized health systems\(^1\). The recommendations also take into consideration the changing biological and ecological factors (insecticide resistance, vector species shifts and transmission ecologies) and economic contexts as programs move from scaling-up control through to the final stages of elimination and prevention of re-introduction of malaria.

Various interventions were carried out in the 1950’s and 1960’s as part of the global malaria eradication programme with considerable success in many regions; malaria was considerably reduced in most of Southern Africa (7) and in some areas of East Africa where transmission was intense, such as Pare-Taveta in border districts of Kenya and what was then Tanganyika (8). This success was achieved almost entirely by IRS along with the use of an effective antimalarial drug for treatment. Where successes were recorded, much was based on the contribution of the vector biologists. Their expertise was essential in understanding the biology, ecology and behavior of species and species complexes within the genus *Anopheles* and their various roles in malaria transmission (9). However By the late 1960s, most vector-borne diseases were no longer considered to be major public health problems outside Africa. Resources dwindled, control programmes collapsed, and fewer specialists were trained and employed (10).

Vector biologists\(^2\) continue in the 21\(^{st}\) century to be essential contributors to the important public health task of controlling malaria. While malaria *disease* is a clinical phenomenon, malaria *transmission* is a biological and ecological process. Malaria control requires both clinical and biological expertise. The entomologist, as a biologist, needs the basic training to analyze the context of malaria transmission and implement and evaluate the most effective means of malaria vector control. In order to respond to the critical and evolving role of biological expertise in malaria control operations, it is essential to broaden the scope of the entomologist to include skills in epidemiology and biostatistics, as well as modern technologies such as geographic information systems (GIS) and satellite-derived data. The knowledge of vector biology, parasitology, and epidemiology is critical to the proper collection and

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\(^1\)Capacity building referred to in this document is for entomology and vector control within national control programmes and it does not include the capacity of research and academic institutions or others. Where this is relevant, however, arrangements can be made to make use of available resources in research and academic institutions

\(^2\)Vector biologists combine skills in biology (entomology and ecology) and disease transmission (epidemiology and biostatistics) and the impact/role of vector control interventions at programme level. In this document, the term vector biologist is used interchangeably with public health entomologist/vector control expert.
interpretation of data and for developing and adapting new strategies to decrease and ultimately interrupt malaria transmission; one needs both a biological and epidemiological approach. The role of the vector biologist is expanding (11); those who have training in epidemiology as well as biology can serve dual roles in the ministries of health. This broad knowledge and capacity also facilitates better career development opportunities in the public health system.

Whereas in some countries vector biologists have career opportunities within the national control programmes of ministries of health, in many others these opportunities are limited or simply unavailable. In the latter case, it is often assumed that the role of vector biologists can be taken on by local research institutions. While linkages between universities and research institutions and the national control programmes are important, especially as reference laboratories and for collaborating on operational research, malaria control operations are not *ad hoc* activities, and demand regular attention from dedicated programme staff. Control programmes require vector biologists who can perform essential routine activities that rapidly inform planning and implementation of vector control. Indeed, without dedicated vector biologists in national control programmes, efforts to scale up vector control interventions for malaria control and eventual elimination will be impaired.

Recent efforts to scale up vector control interventions have not been met with parallel investment in human resources, especially vector biologists, even as some malaria endemic countries have received massive external support. Unless vector control investments are accompanied by concerted efforts to train and employ local personnel to take leadership roles in the health system and take on management responsibilities, this support will not have impact on system strengthening and will not be sustainable. In the words of a public health advisor Socrates Litsios, “*Malaria control depends on the presence of essential public health functions. Health services in tropical malaria countries have not yet developed a public health capacity adequate for the control of malaria. To control malaria under current conditions requires an international response, one that builds national public health capacities capable of fully supporting local initiatives*” (12).

1. Entomological surveillance

Just as surveillance data regarding malaria cases are critical for guiding investments in the diagnostic testing and treatment of malaria, so is entomological surveillance essential for malaria vector control. These data include the basic core entomological indicators, such as: presence and identification of the vector species; insecticide susceptibility status; time and place of feeding and resting; sporozoite infection rates; as well as, depending on the context, additional indicators such as larval habitats, blood feeding habits and longevity. Collecting
these data, linking it to local epidemiological data that may be collected in clinics and health centers, and analyzing it for the implementation of appropriate malaria vector control, requires a cadre with different capacities/skills at the national and sub-national levels in the fields of epidemiology and management as well as entomology and vector control.

**Core entomological surveillance**

Entomological surveillance is the regular data collection and analysis of defined entomological parameters, such as species composition and abundance, insecticide resistance, feeding and resting behaviors and sporozoite infection rates. Collection and analysis of these and other indicators generate the evidence-base for selection of the most appropriate interventions as well as when and where to apply them. Where malaria elimination is the goal, the capacity to regularly monitor vector species abundance, composition, and (where possible) age structure, is key to focusing on remaining transmission areas and to determine receptivity of those areas after the parasite has been eliminated. When this information is coupled with insecticide resistance data, it allows for a rapid vector control response with the most effective tools. In both control and elimination situations, well-trained vector biologists/public health entomologists are needed to run well-informed and efficient vector control programmes.

In many countries, the geography of malaria transmission is heterogeneous. Mapping the presence of the vector (including specific identification where morphologically similar sibling species are present) and insecticide susceptibility status is essential for stratification and efficient use of resources. This is especially important when programs move towards elimination and to more focal interventions. Programmes must also be aware that with ecological changes or with success of vector control interventions, there may be shifts, not just in insecticide susceptibility, but in the vector species composition (e.g. with deforestation *An. dirus* decreases and other “secondary vectors” may have increased importance; with intensified indoor control *An. gambiae* s.s. may decrease as *An. arabiensis* may become the predominant vector) (4). Malaria transmission patterns change in space and in time -- and programmes must have the capacity and the evidence base to adapt.

**Insecticide resistance monitoring and management**

Routine monitoring of insecticide resistance is an essential component of a vector control programme and is the key responsibility of control programmes in ministries of health. In 2012, responding to the threat of insecticide resistance, WHO launched the Global Plan for Insecticide Resistance Management in malaria vectors (GPIRM) (3). This plan calls for specific actions at the national level to monitor resistance and establish resistance management strategies. For example, planning and implementing insecticide resistance monitoring requires the capacity to identify representative sentinel sites country-wide. And this capacity to select appropriate sentinel sites is informed not only by a background in entomology and vector control but also by understanding the epidemiology and clinical management of malaria.

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control, but also by an understanding of epidemiology to determine where problems may occur. The consequences of increasing resistance to currently used insecticides (especially pyrethroids) could be catastrophic, but again our success in meeting this challenge is completely dependent on the human resources and the systems at the national and subnational levels to collect the necessary information and implement an appropriate response.

In countries where capacity for general entomological surveillance is weak, improving the monitoring of insecticide resistance should be the foundation for building a broader and more robust entomological surveillance system.

Different tasks and capacities are required at different levels of the network. Mosquito collections to provide samples for insecticide susceptibility testing are usually done by technicians. These may be Environmental Health Technicians or dedicated malaria field staff. With experience, some of these technicians can also perform the susceptibility bioassays with the standard WHO Tube or the CDC Bottle (13), but in all cases, under the direction of a trained entomologist, usually with either a Bachelor or Master’s degree who may be posted to the national level, but more often would be working at a sub-national level. The analysis and interpretation these insecticide resistance data requires more highly skilled staff, generally with training at least up to the post-graduate level. This need for qualified entomologists currently far outweighs availability, hampering the implementation of GPIRM and our collective ability to respond to this threat of resistance. While some countries have been able to establish technical expert committees to evaluate susceptibility data and make insecticide procurement recommendations, few countries are able to use these data effectively, limiting both national level decision making and global policy refinement.

This lack of adequately trained and supported professionals in insecticide resistance data collection and analysis, and the management capacities for mitigation, needs to be addressed as a matter of urgency.

2. Infrastructure capacity

As part of the entomological surveillance and insecticide resistance monitoring, programmes need infrastructure capacity at different levels of the network. There need to be basic entomological laboratories at the subnational level where morphological identification with microscopes, rearing mosquitoes to the adult stage from gravid females, and larval collections can be accomplished, and susceptibility bioassays can be performed. At the national level, programmes also need access to insectaries and entomological reference laboratories, either within the NMCP or through clear institutional arrangements with National Research and Training institutes. The entomological reference laboratory is required for molecular identification of vector species where morphologically identical sibling species may be sympatric (e.g. *An. gambiae* s.s. and *An. arabiensis*), and for other assays such as sporozoite
detection, blood meal analysis and the identification of insecticide resistance mechanisms. An insectary, with a colony of insecticide- susceptible vector species is necessary for bioassays of the duration of efficacy for the IRS and ITN applications and deployment.

In some countries such facilities may already exist in national universities or research and training institutes. It may be possible for the NMCP to make contractual arrangements with a national institute to provide reference laboratory services, but must be cognizant that this requires a clear financial commitment and that the needs and motivations of a research institute maybe tend more towards upstream research rather than the day-to-day routine entomological monitoring. In such cases NMCPs may want to have as much insectary and laboratory capacity as possible within the programme, without having to rely on other institutions.

Vector control programs also need capacity for basic implementation research to provide answers to local issues such as monitoring the entomological and epidemiological impact of combinations; monitoring the impact if insecticide resistance; the timing and frequency of IRS applications. Coordination with local and, where appropriate, external universities and research institutions is important, but for effective utilization of the results, the NMCP should be responsible for commissioning and coordinating the implementation and dissemination of such research. It is important to ensure that data arising from such work are not held for publication purposes, but immediately shared with control programmes for policy and procurement decisions.

3. Opportunities for expanded information management in the planning, implementation and evaluation of vector control

For vector control interventions such as IRS, LLINs, and larval source management to be effective, it is essential to understand the particular mosquito species present, the insecticide susceptibility status, vector feeding and resting habits, and larval habitat requirements and how these relate in space and in time, to the local transmission ecology.

In the past, an understanding of geographical and ecological factors were central to developing strategies to reduced malaria transmission (14). Known as “species sanitation,” this required precise vector identification and knowledge of its ecological requirements in order to modify the environment and eliminate its role in malaria transmission. While our modern-day approaches include LLINs and IRS, this fundamental understanding of ecology is essential, especially in heterogeneous and changing environments. Data that 20 years ago was being entered by hand and analyzed on main-frame computers can now be largely accomplished by a

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smart phone and a laptop. Many mosquito abatement programmes in developed countries, as well as some NMCPs, have developed simple and robust mapping and information management tools for mosquito surveillance and vector control implementation that incorporate both epidemiological and entomological data necessary for planning vector control interventions.

Control programs must take advantage of this technology revolution and build capacity in skills and resources to manage and analyze surveillance data for planning and implementation. Control programs should also be able to analyze costing and epidemiological data and to incorporate these into spatial or geographical analysis and mapping. Being able to employ these tools to track reductions or expansions of areas with malaria transmission will in the end save the programme money, and is critical to implementing efficient and sustainable control interventions.

4. Revision of current curricula in training institutions to meet the needs of control programmes

During the last decade, many countries have tried to scale up their vector control programmes without adequate and well-skilled entomologists. Moreover, in some countries, as the entomologists retired from service or moved on to other work, there were no young entomologists adequately trained to replace them. A cadre of staff at different levels with different skills are needed, ranging from field technicians to provincial or state-level staff to postgraduate vector biologists at the central level. Further work is needed to define the ideal numbers of such professionals at national and subnational levels.

There is no agreed-upon core curriculum to train vector biologists; they often start with a general degree (i.e. biology or medicine), and then continue their studies to specialize in fields that are appropriate to their interest. In some control programmes, the technicians may have no training in biology or entomology, but only in environmental health (Namibia, Sudan) or other paramedical fields. This diversity of backgrounds, and the inadequate or haphazard training, results in control programmes with different strengths in entomological surveillance and vector control operations, including skills for basic implementation research necessary to adapt and optimize programme investments. However, WHO published in 2012 a core curriculum for integrated vector management” (15) and is currently publishing a training module on malaria control for malaria entomology and vector control (16).

Irrespective of background, most control programme entomologists and vector control experts have been trained in academic institutions and only acquired the necessary practical field skills through experience by working in a control programme environment. On the other
hand, the curriculum for post-graduate entomology training in academic institutions is usually very broad, with an aim to train students who will eventually continue on to work in a research or teaching institution. Rarely is the training tailored to the specific public health, practical field needs of malaria and other vector-borne diseases control programmes. This requires moving from the traditional notion of the “Medical Entomologist” who may focus solely on the vector itself, its molecular biology and biochemistry, to the “Public Health Entomologist” or “Vector Biologist” who is equipped with the basic ecological and entomological skills but is also a public health practitioner, skilled in epidemiology and programme management.

As malaria control becomes more focal, there is a need to train staff with specific skills at the periphery level through in-service training and mentoring under the direction of well-trained central level staff. Training institutions need to work closely with control programmes and other partners to develop training programmes that meet these capacity needs in a changing health system (2 and 12). Given the different capacity needs listed elsewhere in this document, a mix of training and skill levels is necessary to generate a competent and complete vector control programme. Control programmes should include vector biologists with basic training in biology, entomology, ecology, and epidemiology as well as program management.

As detailed below under the recommendations to countries, countries should conduct a needs assessment, and revise curricula, as well as job descriptions and career structures, with the support of WHO and partners to train and support this new generation of public health professionals, entomologists and vector control specialists.
Examples of capacity strengthening for national malaria control programmes

**African Network on vector Resistance (ANVR):** In Africa south of the Sahara, the African Network for Vector Resistance to Insecticides has played a role in capacity-building. It has prepared frameworks and protocols for resistance surveillance and management for its member countries and has supported them in collecting and publishing information on insecticide resistance in Africa. It has also fostered collaboration between control programmes and research institutes at national and international levels and, with WHO, organized training in entomology in many countries. An important aspect of the ANVR is the on-going communication and mentoring made possible through the network.

**The International Master Degree in Entomology (IME):** The international Master of Science Degree in Entomology was established in 2006 in collaboration with the Institute for Research and Development (IRD), Montpellier and Abomey Calavi universities and the entomological Research Centre of Cotonou (CREC) in Cotonou, Benin. The content of the course includes systematics, biology and ecology of vectors of medical interest, epidemiology and control. The course begins in September in Cotonou for 4 months, with a field trip in Burkina Faso in November and 5 months (January-June) of intensive laboratory work. Until 2012, a total of 91 students have graduated from this course from 24 different countries, mainly Benin (11), Burkina Faso (11), Cameroon (10) and France (13). Out of the 91 graduates, 38 have undertaken a PhD and 26 are now working in national research institutions or in the national vector control programme. The cost for the course is about Euro 12,000.

**Master of Science Degree in Medical Entomology and Vector Control:** The WHO Eastern Mediterranean Region (EMRO) has invested heavily in building entomological capacity to support national malaria control programmes, following a Regional Committee resolution\(^5\) to establish a Regional MSc course in entomology and vector control. Investment in the MSc course, established in collaboration with the Blue Nile Institute, Gezira University, Sudan, the London School of Hygiene and Tropical Medicine, the Liverpool School of Tropical Medicine (United Kingdom) and Witwatersrand University in South Africa, has produced a large cadre of vector control programme staff (80 people have been trained over the past 3 years), who can support entomological surveillance and vector control in about 12 countries of EMRO and AFRO. The curriculum developed for this course (4 months coursework, 4 months field work and 4 months research and dissertation) was also adapted for national training efforts in Iran and Pakistan (10). Fellowships to cover tuition fees and stipend (USD 10,000 per student) were provided by WHO as part of its financial contribution to and in agreement with respective Member States.

**Diploma Courses in Integrated Vector Management:** In the WHO Western Pacific Region, training and diploma courses in integrated vector management have been organized for insecticide resistance monitoring in the context of both dengue and malaria. As the recommendations of the GPIRM for insecticide resistance management strategies are implemented, capacity in entomology and vector control in all the WHO regions will be a key asset.

**Training Module on Malaria Entomology and Vector Control:** WHO is currently publishing a training module on malaria control for malaria entomology and vector control. The training document is designed primarily to help health personnel involved in the planning, implementing and evaluation of malaria vector control activities but also for those responsible with the training of such personnel. The training document has been updated in line with current vector control policies and guidelines/guidance.

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\(^5\) Fifty-second Session of the Regional Committee for the Eastern Mediterranean (2005), Resolution EM/RC52/R.6 on Integrated vector management
5. Institutional arrangements - vector control structures and services

The placement of vector control in ministries of health varies from country to country. In most highly endemic malaria countries there is a unit of vector control within the NMCP responsible for the overall planning, monitoring and evaluation, and implementation of malaria vector control. In such countries, there is usually a director of NMCP – supported by at least three Deputy Directors, typically for vector control, monitoring and evaluation, and case management. In many countries outside the WHO African region, the vector control unit may also be responsible for control of other vectors, such as for dengue, visceral leishmaniasis, Chagas and filariasis.

In some countries, especially those where malaria is not seen an important vector-borne disease, there is usually a vector control section as part of the environmental health and sanitation department within the ministry of health (Morocco, Bahrain). This is the structure in a number of countries in the Eastern Mediterranean Region. In exceptional cases, the vector control is not with the ministry of health, but with the ministry of environment or local government (Singapore).

Sometimes, the NMCP may have one or two dedicated vector control staff responsible for the coordination and implementation of malaria vector control, especially the ITN and IRS activities, but not for routine monitoring activities. Here, routine entomological monitoring activities may be done by a local university or research institute (Iran, Kenya, Tanzania). This can sometimes be problematic when routine activities are neglected in favor of research priorities that may not provide immediate benefit to the control programme, or when the data collected, e.g. insecticide susceptibility data, is held for future publication rather than immediately shared for resistance management decisions.

While it is important to take into account local settings when addressing institutional arrangements for entomology and vector control, an effective vector control programme is one with both central and peripheral structures and responsibilities (Sudan). This may sometimes be difficult in a decentralized health system, but there need to be clear structures for technical support and accountability - as resources and staffing intended for entomological monitoring and vector control may be directed elsewhere. Similarly, other equally important vector-borne diseases, such as dengue, may suffer because resources have not been allocated to address them. To fulfill the diversity of roles and responsibilities in any particular country, regardless of where vector control is placed, public health entomologists with diverse skills are needed.

Due to the overlap in responsibilities for vector control between malaria and other vector-borne diseases, as well as the diversity of situations in different countries, WHO promotes Integrated Vector Management (IVM) as the overarching framework to guide strategy (13). IVM is defined as A rational decision-making process for optimal use of resources for vector control and includes not just the “evidenced-based decision making” from improved
entomological surveillance and intervention monitoring, but also elements related to the sustainability and efficiency of the overall program. It is in the framework of this approach that intersectoral coordination between different sectors and appropriate institutional arrangements for vector control within ministries are addressed and strengthened.

6. Career opportunities for public health entomologists

Along with training and mentoring for national entomology and vector control services, it is critical to provide career structures for these personnel. Commonly, within a hierarchy dominated by the medical profession, career opportunities and leadership positions for the public health vector biologist may be a big challenge. In medically-oriented institutions such as most ministries of health, where career advancement is oriented toward medical qualifications rather than public health or biology qualifications, it is difficult to integrate career opportunities for scientists into the system. Young, eager graduates who want to pursue a career in vector-borne diseases look at the life-long opportunities between an upstream research institution and downstream public health control programme.

As described throughout this document, public health entomologists and vector biologists are needed in ministries of health. Some countries have succeeded in establishing effective public health programmes with scientists in leadership positions. Some national programs, such as in Myanmar, have clearly defined cadre with different training and job descriptions, ranging from the national senior entomologist, to entomologists at the state level, assistant entomologists, and finally to the foundation of mosquito collectors. Some national programs rotate staff responsibilities on a seasonal basis in an attempt to maximize programmes with limited employees (Myanmar); mosquito collectors or assistant entomologists may be focused on entomological monitoring for only certain months of the year, for example, alternating perhaps as environmental health officers during the rest of the year.

But whatever the exact civil service structure and retention schemes operate in the country, as part of an overall national capacity building plan, there is a need to critically address the job descriptions and the career structures for technicians, mid-level entomology and vector control staff and national level public health entomologists. The recommendations following include a number of specific actions to be undertaken at the national level, with support from WHO and partners to inventory and revise post descriptions, to establish career development opportunities and to develop a system whereby a young, newly qualified technician or vector biologist will pursue a career in the field, where their skills are so critically needed.
7. Donor coordination for capacity building

In the past, WHO played an important role in the training of entomologists and vector control experts to support the work of control programmes in disease endemic countries. Their staff was also directly involved in supporting countries in the implementation of vector control interventions – including monitoring and evaluation. For example, in 1982, WHO had twenty-four entomologists in country offices, seven across all six Regional Offices, and seven at WHO headquarters. With those numbers, it was already considered a human resource crisis in the area of entomology and vector control (14). However, currently, there are only fourteen PhD entomologists across all of WHO (four in WHO headquarters, five across the Regional Offices and five across the country offices). Of these, only two work solely on malaria vector control (one in WHO headquarters and one in AFRO). Among the other twelve, nine work on other vector-borne diseases, two on health and environment, and one on research. With the current level of investment in vector control interventions, WHO’s support is inadequate, both in its normative role as a source of strategic and policy guidance for malaria control, as well as in its ability to directly support the realization of in-country implementation.

With regard to implementation, it could be argued that there are more partners supporting countries today than in the past. However, many focus more on short-term project implementation rather than on long-term programme development to ensure sustainability. There are sometimes enormous investments in vector control activities, but implemented by the donors and contractors, that while adhering to a common national plan place less emphasis on capacity strengthening and turning over management responsibility to the national programmes, planning for the day that the project will end. With this changing landscape, donor emphasis and coordination for capacity building at both the regional and national level is essential, there need to be clear strategies and a long-term vision for building and sustaining a new generation of public health entomologists and vector biologists who will manage national activities long after the donor leaves and the project ends.

Supporting this long-term vision for sustained and effective vector control is a concerted and coordinated effort to build a network of training and mentoring opportunities for public health entomologists and vector control specialists. Under the continued leadership of WHO, areas for partner support should include the development and revision of curricula and support for regional courses and prototype curricula that can be adapted for national training institutions; identification and where relevant, strengthening of the institutions to host proposed regional training courses using the revised curriculum; and fellowships for potential candidates for both short- and long-term training.
8. Conclusions and recommendations

This paper outlines the rationale and the capacity needs in malaria vector biology and control. It identifies gaps and opportunities, not just for training, but for continued mentoring and the establishment of clear job descriptions and career structures for cadre from the basic technician and mosquito collector to the national vector control programme manager. There are specific entomological parameters that must be addressed if we are to sustain the current fragile gains achieved over the past decade and make progress towards malaria elimination.

Responding to the threats of insecticide resistance, improving efficiencies to maintain coverage, developing innovative tools and strategies to address transmission beyond traditional IRS and ITNs, and in the context of Integrated Vector Management, develop an evidence-based, rational decision-making process to optimize resources for vector control, depends on human resources and the systems to support them.

Expanding the potential and the interest for careers in vector biology and control is essential. This can be done by expanding the role of the traditional medical entomologist by adding knowledge in public health, programme management, technology skills, especially GIS, and data management, and providing a role in designing and monitoring new interventions. The role must be expanded from a medical to a public health entomologist, from a technician to a leader, an implementer and problem-solver, with a broader range of technical and management skills that can provide a fulfilling life-long career and an essential service to national health and development.

Key recommendations:

Countries to:

- ensure the presence of a functional intersectoral coordination mechanism with a sub-committee for capacity building responsible for developing a long-range strategic plan for building human resources and systems for public health entomology and vector control – including malaria;
- strengthen intersectoral collaboration with ministry of education, and with universities and in-service training programmes to ensure that public health entomology and vector control (including epidemiology and management) is included in curricula and educational activities;
- ensure that posts and career development and structures for entomology and vector control experts are established at national and subnational levels within ministries of health or other appropriate government structures;
- establish institutional arrangements among universities, training and research institutions and the national malaria control programme to support ongoing training and support for entomologists and vector control experts;
• conduct training needs assessment and curricula review for pre-service and in-service training, following guidelines to be developed by WHO;
• ensure that there are sufficient resources for human and infrastructure capacity building factored into bi-lateral and multi-lateral projects/programmes and funding requests based on costed national strategic plans.

Partners to:

• ensure that all support to countries has a strong component of capacity building to include short and long-term training and mentoring as well support for the necessary entomological laboratory and insectary resources.
• ensure national “ownership” in all the technical and management activities;
• support national control programmes in clearly defining and implementing strategies to ensure that human and technical resources and systems are adequate to sustain and expand vector control efforts after partner support ends.
• Support global and regional efforts to revise curricula and make available training and on-going mentoring opportunities for national staff

WHO to:

• support countries in the mobilization of resources (human and financial) to implement capacity building activities;
• facilitate the needs assessment for capacity building in public health entomology and vector control as part of a broader assessment of human resources for malaria control and elimination;
• support relevant institutions and partners in revising and adapting appropriate curricula in entomology and vector control that address the needs of vector control programme staff at national and sub-national levels;
• develop prototype strategic plans for capacity building and facilitate the development and dissemination of training materials on public health entomology and vector control;
• support regional and global collaboration networks (including resource mobilization) for training, technical advice and continued mentoring for entomological monitoring and vector control operations; and
• support a clearly defined advocacy strategy for public health entomology and vector control professionals, developed in collaboration with global, regional and national partners.
9. References