Online interactive platform for mapping reports of insecticide resistance in malaria vectors

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Introduction

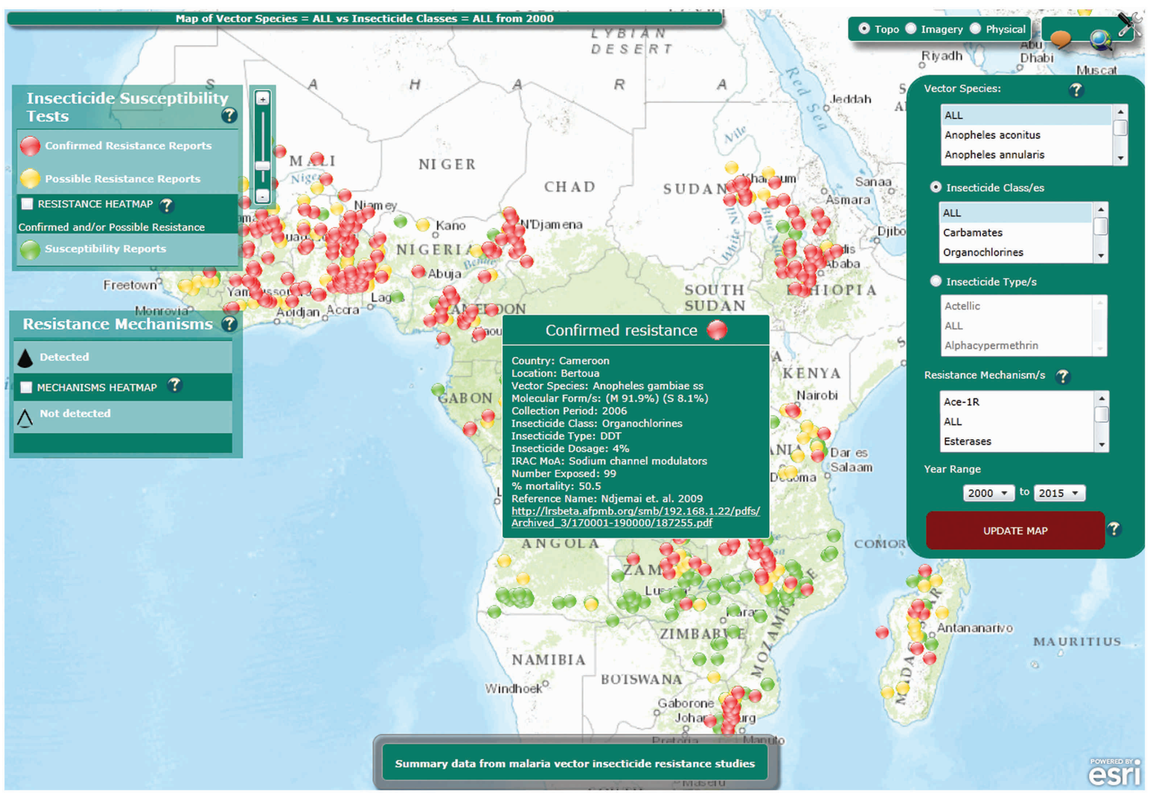
The two major insecticide-based malaria interventions - indoor residual spraying and treated bed nets - have led to significant reductions in malaria morbidity and mortality. However, the emerging and rapid spread of resistance to major classes of public health insecticides threatens current malaria vector control efforts. Deployment of the most appropriate tools needs to be informed by up-to-date data on insecticide resistance in target malaria vector species. However, to date data have been fragmented into various databases with varied sources, formats, scopes and depths, precluding usage for prompt decision-making.

An online geospatial application called IR Mapper **(www.irmapper.com)** was developed to address the need for a standardised database for insecticide resistance information. This application consolidates all published data on insecticide susceptibility and resistance mechanisms in *Anopheles* malaria vectors, and presents it in a user-friendly format via interactive maps.

Methodology

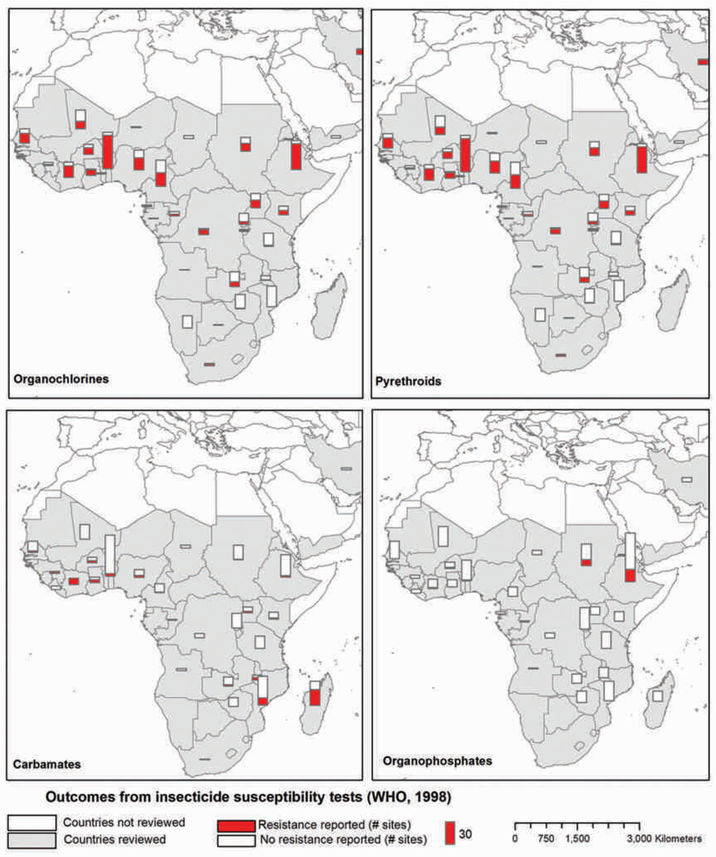
Data were extracted from publications in English and French scientific journals as well as from IRBase (2012). Additional unpublished data derived via standard methods were sourced from reports by the President's Malaria Initiative (2012), National Malaria Control Programmes and other reputable institutes. Mosquito collection locations and dates, vector species, molecular form/s, insecticide type and concentration, number of mosquitoes tested, mortality outcomes and corresponding status determined by WHO susceptibility tests (WHO 1998) were compiled. Results from biochemical and molecular analyses for resistance mechanisms eg. *kdr* (L1014S and L1014F), Ace-1R mutation frequencies, and comparative up-regulation of metabolic enzymes (oxidases, esterases or GSTs) were recorded. Data from 1959-2012 were compiled into an Excel spreadsheet consisting of 26 unique field names and 6,282 unique field records from 1,303 geo-referenced localities in 48 countries. Data were obtained for 47 *Anopheles* species or species complexes.

Data were projected on the online geospatial application **IR Mapper**, which operates on a Microsoft Silverlight platform. The interactive interface allows filtering and projection of data on maps based on a set of user-directed criteria which include vector species, chemical class or type and the mechanism of resistance. Assay-specific information is displayed in pop-up boxes which also provide a URL to the source document. A 'Heatmap' feature showing proportion of confirmed and/or possible resistance, and tested/detected resistance mechanisms is also available. A time filter enables visualisation of changes in susceptibility status over specific periods of time.



Results

Number of sites per country for which insecticde resistance was reported in *Anopheles spp*. between 2000 and 2012



Since 2000 for the 48 countries surveyed:

- Resistance was reported in 47 *Anopheles* species in 37 countries to at least one of the four adulticide classes (organochlorines, pyrethroids, organophosphates, carbamates)
  - Countries with reported resistance to all four classes included Benin, Burkina Faso, Cote d'Ivoire, Ethiopia, India, Sri Lanka and Sudan.
  - No reports of resistance were found for Gabon, Namibia, Swaziland, The Gambia, Mauritania and Yemen, although limited monitoring data were available for these countries.
  - Resistance to organochlorines was the most frequently reported (35 countries), followed by pyrethroids (31 countries), carbamates (18 countries) and organophosphates (8 countries).

- Resistance mechanisms data were available for 37 countries, with one or more resistance mechanisms detected in *Anopheles* species from 35 countries.
  - *kdr* mutations (L1014F and/or L1014S) were detected in 30 countries
  - Insensitive acetylcholinesterase was detected in 10 countries.
  - Metabolic resistance mechanisms (including upregulated oxidases, esterases or GSTs) were detected in 18 countries

Planned updates to IR Mapper

IR Mapper is still in beta stage and as such, a few bugs have been encountered in the course of its use. Several improvements and additional features have been prioritized for implementation:

- Migration to ArcGIS for Javascript API platform to improve the speed of data loading and allow offline querying of database
- Correct symbol scaling and order of loading of operational layers
- Heatmaps enhanced to ensure representation of proportion of resistance reports for an area
- Option to display data based on old and new WHO susceptibility status criteria
- Inclusion of a 'view data' function that allows users to map their own IR data in real time
- Inclusion of an 'add data' function for easy upload of quality-checked data by administrators
- Print functionality added to allow direct printing of tailored maps

Conclusion

Data on phenotypic resistance status and resistance mechanisms can be used to identify where there are current gaps in our knowledge, such as in countries or specific regions that experience high malaria burden. Concurrent interpretation of data from WHO susceptibility tests and mechanisms investigations is crucial to support rational deployment of existing tools. Information available on IR Mapper can be used to support evidence-based deployment of essential vector control tools, such as LLINs and IRS.

References

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Acknowledgements

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