Institution: University of Oxford

Unit of Assessment: UOA5

Title of case study:

Mapping vector-borne diseases to inform global planning for control and elimination

1. Summary of the impact

Innovative research into the spatial ecology of vector-borne disease at the University of Oxford led to the setting up of the Malaria Atlas Project (MAP), a programme which has provided sophisticated models of malaria distribution to inform planning and policy decisions of national governments and international agencies. MAP data underpinned the 2012 World Health Organization World Malaria Report and has influenced WHO's policy on malaria. Mapping has also been used in planning and resource allocation by other key players in the fight against malaria: the African Leaders Malaria Alliance, the Roll Back Malaria partnership, the Global Fund and the Global Health Group. More recent research to map the global distribution of dengue risk has been used in vaccine planning by the GAVI Alliance in conjunction with the Gates Foundation.

2. Underpinning research

Vector-borne diseases constitute some of the biggest threats to global public health. Malaria risk affects almost half the world's population; the WHO World Malaria Report 2012 estimates that in 2010 there were 219 million cases of malaria and 660,000 deaths. Dengue fever is ranked by WHO as the most important mosquito-borne viral disease in the world; a 30-fold increase in incidence over the last 50 years means it now threatens around 2.5 billion people worldwide. The effective targeting of available resources in order to control and eliminate these diseases requires accurate and detailed information about their global distribution.

Research led by Professors David Rogers and Sarah Randolph at the University of Oxford's Department of Zoology investigated the ecology and epidemiology of vector-borne diseases such as the African trypanosomiases, yellow fever and malaria. A paper published in 1993 was one of the first to address key factors such as the impact of increasing urbanisation, international trade and climate change on the global spread of vector-borne diseases. The paper identified the need for more complex maps of disease distribution that incorporated, for example, satellite data on weather that might help predict changes in vector distribution[1].

A collaboration developed with Professor Robert Snow, Professor of Tropical Public Health at the University of Oxford, who had also recognised the need to map malaria risk more accurately. Research published in 1998 by Rogers, Simon Hay (also by this time at the Department of Zoology) and Snow represented the first attempt to use remote sensing and geographical information system techniques, in conjunction with data on malaria endemicity to examine the clinical consequences of vector, parasite and human contact in Kenya. Previous studies had merely mapped mosquito habitats and predicted insect numbers. The 1998 paper demonstrated for the first time that a significant correlation existed between the timing of meteorological and vegetation changes (recorded by satellite sensors) and the relative changes in prevalence of clinical malaria[2].

In 2005 a groundbreaking paper provided an entirely empirical approach to the global distribution of malaria using a combination of epidemiological, geographical and demographic data[3]. It showed that there were an estimated 515 million episodes of clinical *Plasmodium falciparum* malaria (the most dangerous form) worldwide in 2002 – up to 50% higher than those reported by WHO, and 200% higher for areas outside Africa. These results reflected the extent to which WHO was relying on passive national reporting for these countries and revealed Africa as the dominant contributor to the global burden of malaria, while highlighting a hidden burden in Asia. It also emphasised the need for an informed understanding of the cartography of malaria risk in order to properly evaluate

the global extent of the disease. The interest generated by this paper led directly to the founding of the Malaria Atlas Project (MAP) in 2006[4]. The Wellcome Trust provided funding, and in 2009 a paper was published describing the research behind the first new global malaria map for 40 years, which showed *P. falciparum* endemicity in 2007[5]. Hay's novel contribution to this was to apply a Bayesian statistical framework in order to create continuous spatial estimates of malaria distribution from the nearly 8,000 fixed-point parasite rate surveys. The research showed that, of the nearly 1.4 billion people exposed to stable *P. falciparum* risk worldwide in 2007, around 55% lived in conditions of very low endemicity with the potential for malaria to be eliminated altogether. It also identified the areas of high risk where a much more aggressive control strategy was needed.

More recently Professor Hay and his group have expanded the scope of their research to study the distribution of many different diseases and identify those with the strongest rationale for mapping. A 2013 paper from the IDAMS Consortium, led by Hay, analysed the global distribution of dengue fever risk, and used mapping techniques to estimate that there were 390 million dengue infections per year, of which 96 million manifested clinically – more than three times the dengue burden estimate of the World Health Organization[6].

3. References to the research

1. Rogers DJ, Packer MJ. (1993) Vector-borne diseases, models, and global change. Lancet 342: 1282–1284. doi: 10.1016/0140-6736(93)92367-3 ***Paper identifying the need for more complex maps of disease distribution incorporating remotely-sensed data.***

2. Hay SI, Snow RW, Rogers DJ. (1998) Predicting malaria seasons in Kenya using multitemporal meteorological satellite sensor data. Trans Royal Society of Tropical Medicine and Hygiene 92: 12–20. doi: 10.1016/S0035-9203(98)90936-1 ***First demonstration of a correlation between changes in weather and vegetation data obtained from satellites, and relative changes in prevalence of clinical malaria.***

3. Snow RW, Guerra CA, Noor AM, Myint HY, Hay SI. (2005) The global distribution of clinical episodes of *Plasmodium falciparum* malaria. Nature 434: 214–217. doi: 10.1038/nature03342 ***Key paper describing the global distribution of malaria and highlighting areas in which existing data was inaccurate or missing. Winner of the Research Paper of theYear award from the Malaria Foundation International in 2006.***

4. Hay SI, Snow RW. (2006) The Malaria Atlas Project: Developing global maps of malaria risk. PLoS Medicine 3: 2204–2208. e473. doi: 10.1371/journal.pmed.0030473 ***Paper launching the Malaria Atlas Project, underlining the need for improved maps of malaria distribution and prevalence.***

5. Hay SI, Guerra CA, Gething PW, Patil AP, Tatem AJ, Noor AM, et al. (2009) A world malaria map: *Plasmodium falciparum* endemicity in 2007. PLoS Medicine 6: 0286–0302. e1000048. doi: 10.1371/journal.pmed.1000048 ***Paper describing the research and methods behind the first comprehensive global malaria map for 40 years.***

6. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. (2013) The global distribution and burden of dengue. Nature 496: 504–507. doi: 10.1038/nature12060 ***First systematic mapping of the global distribution of dengue fever.***

Funding for research: Grants in excess of £4M have been received for this work since 1998 from the Wellcome Trust, the Bill and Melinda Gates Foundation, the Global Fund and a number of smaller foundations.

4. Details of the impact

The critical impact of Professor Hay and colleagues' research has been in the provision of detailed, accurate and evolving information about the distribution of vector-borne diseases (particularly malaria). The information has enabled the more effective targeting of available resources. Worldwide, control of malaria is high on the political agenda, but WHO estimates that the large

amount of international funding spent each year on control measures (US$2.5 billion in 2010) is less than half of what is ideally required.

Since the first map of *P. falciparum* transmission, the Malaria Atlas Project has gone on to develop increasingly sophisticated models of the spatial and temporal patterns of global malaria, based on the research described above. MAP, which continues to operate out of the Department of Zoology, now provides a definitive and continuously updated open access mapping resource describing the distribution of malaria in every affected country in the world[7]. The MAP website receives an average of 70,000 hits from around 216 nations every year (including visits from 97 of the 100 malaria endemic countries), and since 2008, MAP data have been used to help shape malaria policy and practice. For example, in 2012 the African Leaders Malaria Alliance (ALMA), an alliance of 49 Heads of State and Government, used analyses based on MAP's open access map of *P. falciparum* transmission to explore how effectiveness of insecticide treated nets (LLINs) might vary from country to country. This analysis highlighted priority areas in Africa for targeting of LLINs and through the Global Fund (an international financing institution dedicated to attracting and disbursing resources to prevent and treat HIV/AIDS, TB and malaria) resulted in significant additional resourcing: 38 million LLINs in two countries, and US$117M for LLINs in three others. The Chief Technical Advisor to the ALMA Secretariat confirms that the data provided 'was vital in convincing partners as to the seriousness of the situation in the identified countries' and 'extremely useful to ALMA in making the case for targeted investment in filling the LLIN gaps in several countries'[8].

Since 2008, MAP has had its biggest impact in terms of influencing WHO policy on malaria. While WHO's role is primarily advisory, it is powerfully influential at the level of national governments and sets the health agenda at a global level. The prevention and control of malaria is, together with HIV/AIDS and tuberculosis, at the top of WHO's list of priorities. Since 2012 MAP has made substantial contributions to WHO's annual World Malaria Report[9], which is 'used widely in international and national level policy decision making' according to the Director of WHO's Global Malaria Programme. He also confirms that 'as well as their maps of malaria transmission and estimates of clinical incidence, MAP have provided information on the equitable distribution of funding for malaria control, the rational distribution of insecticide treated bednets ... and a range of other analyses provided responsively.' This demonstrates the extent to which WHO considers MAP data to represent the 'gold standard' for malaria mapping. MAP is in the process of becoming a WHO Collaborative Centre to cement a joint approach to malaria burden estimation[10].

MAP data also underpin the strategies of the Roll Back Malaria (RBM) partnership which was launched in 1998 by WHO, UNICEF, the UN Development Programme and the World Bank, in an effort to provide a coordinated global response to the disease. For example, the maps used from March 2010 in several of RBM's 'Progress and Impact' reports are provided by MAP, and Professor Hay was a co-author of the report on 'Mathematical Modelling to Support Malaria Control and Elimination', in which RBM stressed that 'mathematical modelling can play a critical role in navigating complex public health decisions'[11]. The Global Fund uses MAP numbers and maps to analyse where interventions are needed, assess the level of intervention required and evaluate subsequently the usefulness of interventions. In 2012 it collaborated closely with Hay and others on a comprehensive review of funding for malaria control, which established that current patterns of funding were inadequate and unequal[12].

As well as supplying open-access data, MAP works with interested parties to create maps revealing specific information. They have been engaged in a large-scale project with the Global Health Group at the University of California, San Francisco, whose goal is to stimulate practical international and local action to solve critical health challenges. Supported by grants from the Bill & Melinda Gates Foundation and ExxonMobil, its Malaria Elimination Initiative aims to identify and assess the countries which could feasibly become malaria-free in the near future. MAP has provided in-depth mapping and assessment for all countries that are determining their path toward malaria elimination and the collaboration has generated two malaria elimination atlases[13]. The Director of the Global Health Group states that 'the atlases [for which he confirms that MAP provided the detailed mapping] have contributed to national and regional malaria elimination

strategy, and have strengthened political and financial support for malaria elimination'[14].

Recent research into the global distribution of dengue fever risk has already led to a significant impact with the GAVI Alliance, a public-private partnership focused on increasing access to immunisation in developing countries. Detailed maps were produced to show levels of dengue risk in all 54 GAVI-eligible countries, and to identify where data were in most urgent need of update to improve dengue burden predictions[15]. In conjunction with the Gates Foundation, GAVI has used the results of the research to inform its planning strategy; the Senior Program Officer for Neglected Infectious Disease at the Bill & Melinda Gates Foundation states that Hay's work 'has helped build the evidence base that the Bill & Melinda Gates Foundation, in partnership with GAVI alliance and others, is using to evaluate the pros and cons of including a future dengue vaccine to its vaccine portfolio for developing countries. Our strategy development has been guided and informed by having this robust data platform'[16].

5. Sources to corroborate the impact

7. Malaria Atlas Project. Available from: http://www.map.ox.ac.uk/ ***The MAP website is the gateway to the assembled data and cartographic products widely available in the public domain (>3000 available). Data on website hits can be corroborated by staff at the Department of Zoology.***
8. Supporting statement from the Chief Technical Adviser to the ALMA Secretariat, confirming the contribution that MAP data made to effective and efficient malaria prevention and control interventions in Africa (held on file).
9. WHO's World Malaria Report 2012 (held on file), and also available for download from http://www.who.int/malaria/publications/world_malaria_report_2012/en/ ***Corroborates in the Acknowledgements pages the contributions made by MAP.***
10. Supporting statement from the Director of WHO's Global Malaria Programme, corroborating the contributions made by MAP to WHO documents and decisions (held on file).
11. Roll Back Malaria Progress and Impact Series. Available from: http://rbm.who.int/ProgressImpactSeries/ (also held on file). ***In addition to key cited report, MAP data is used in 'Defeating Malaria in Asia, the Pacific, Americas, Middle East and Europe' and 'A Decade of Partnership and Results'.***
12. Pigott DM, Atun R, Moyes CL, Hay SI, Gething PW. (2012) Funding for malaria control 2006-2010: a comprehensive global assessment. Malaria J. 11: 246. doi: 10.1186/1475-2875-11-246 ***Review examining the way malaria control funding is allocated, confirming financial support from the Global Fund, and also close collaboration: co-author Professor Rifat Atun was Head of Monitoring and Evaluation at the Global Fund when the review was written.***
13. University of California, San Francisco Global Health Group. Publications - Malaria Elimination Group 2009. Available from: http://www.malariaeliminationgroup.org/publications ***Both the Atlas of Malaria Eliminating Countries 2011 and the Atlas of the Asia Pacific Malaria Eliminating Network are confirmed as having been produced in partnership with MAP.***
14. Supporting statement from the Director of the Global Health Group, University of California, San Francisco (held on file), corroborating the significant contribution made by MAP to the atlases detailed in reference 13.
15. Messina JP, Brady OJ, Hay SI. Dengue risk and burden estimates in GAVI countries. Spatial Ecology and Epidemiology Group, Department of Zoology, Oxford University. Available from: http://simonhay.zoo.ox.ac.uk/uploads/publications/181/Messinag%20Dengue%20GAVI%20(2013).pdf ***Hay and colleagues' detailed mapping of the dengue burden worldwide.***
16. Letter from Senior Program Officer for Neglected Infectious Disease at the Bill & Melinda Gates Foundation, corroborating the contribution Hay's research made to their dengue strategy.