

## Perspective Piece

### What is a Hotspot Anyway?

Justin Lessler,<sup>1\*</sup> Andrew S. Azman,<sup>1,2†</sup> Heather S. McKay,<sup>1†</sup> and Sean M. Moore<sup>1†</sup>

<sup>1</sup>Department of Epidemiology, Johns Hopkins University, Baltimore, Maryland; <sup>2</sup>Medecins Sans Frontieres, Geneva, Switzerland

**Abstract.** The importance of spatial clusters, or “hotspots,” in infectious disease epidemiology has been increasingly recognized, and targeting hotspots is often seen as an important component of disease-control strategies. However, the precise meaning of “hotspot” varies widely in current research and policy documents. Hotspots have been variously described as areas of elevated incidence or prevalence, higher transmission efficiency or risk, or higher probability of disease emergence. This ambiguity has led to confusion and may result in mistaken inferences regarding the best way to target interventions. We surveyed the literature on epidemiologic hotspots, examining the multitude of ways in which the term is used; and highlight the difference in the geographic scale of hotspots and the properties they are supposed to have. In response to the diversity in the term’s usage, we advocate the use of more precise terms, such as “burden hotspot,” “transmission hotspot,” and “emergence hotspot,” as well as explicit specification of the spatiotemporal scale of interest. Increased precision in terminology is needed to ensure clear and effective policies for disease control.

Over the past decade there has been increasing interest in geographic disease “hotspots,” particularly for infectious diseases. This includes calls to target hotspots in public health practice.<sup>1–3</sup> For example, at a 2013 meeting of the Reference Group on Estimates, Modeling, and Projections, the Joint United Nations Program on human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS) focused on the urgent need to prioritize interventions that target geographic areas of concentrated HIV epidemics, recommending the use of novel geospatial “hotspot” analyses to inform resource allocation and programmatic goals.<sup>4</sup> The third phase of the U.S. President’s Emergency Plan for AIDS Relief also calls for data-driven geographic targeting of interventions, though the term “hotspot” is not used.<sup>5</sup> Likewise, a November 2015 Consultative Meeting on Strategic Approaches for Cholera Preparedness and Response in the World Health Organization-Eastern Mediterranean Region recognized the mapping of cholera “hotspots” as an integral component of a regional framework for cholera control. Similar recommendations to focus on hotspots has been part of strategic plans for Ebola,<sup>6</sup> malaria,<sup>7</sup> and emerging pandemic threats.<sup>8</sup>

Despite its increasing use in policy documents, the term “hotspot” is vague and rarely defined precisely. This ambiguity can generate confusion. For instance, at the December 2014 Cholera Round Table in Kinshasa the focus was on targeting cholera hotspots; but attendees expressed considerable confusion about precisely what a hotspot was and how it differed from previous concepts like cholera “sanctuaries.” Such confusion can have significant repercussions, potentially leading to misinterpretation of policy recommendations or misallocation of resources in countries that can ill afford to do so. Hence, clarity and precision are needed in the use of this evocative term.

This article aims to provide a perspective on the use of the term “hotspot” in the public health literature, highlighting

subtle differences in usage that may cause confusion in scientific and policy discussions. The origins and broader uses of the term provide some context for understanding the different ways “hotspot” is used in infectious disease epidemiology and public health. In the medical literature, the term hotspot was first used to describe a region of inflamed or irritated skin.<sup>9</sup> This usage as a term of increased intensity continues in radiology,<sup>10,11</sup> and is analogous to references to hotspots as areas of increased risk or incidence in epidemiology and other fields.<sup>12–17</sup> In contrast, “hotspot” has long been used in genetics to refer to a highly polymorphic area in an organism’s genome,<sup>18</sup> where, for instance, cancer-causing mutations are likely to occur,<sup>19,20</sup> or hypervariability allows a pathogen to evade the immune response.<sup>21</sup> This usage is analogous to how “hotspot” is used when referring to areas of frequent emergence of novel pathogens.<sup>22</sup> However, even within these broad categories, definitions can be unclear and subtle differences can have important implications.

#### HOTSPOTS AS AREAS OF ELEVATED DISEASE OCCURRENCE OR RISK

In infectious disease epidemiology, “hotspot” is frequently used to refer to areas of elevated disease burden or high transmission efficiency. The term has gained traction in the study of malaria, where it has been used to describe groups of small areas (often less than ½ km<sup>2</sup>) with elevated incidence,<sup>23,24</sup> similarly sized units of elevated transmission intensity,<sup>2,25</sup> larger spatial units of elevated incidence (e.g., districts),<sup>26</sup> and even countries with a high burden of disease.<sup>1</sup> The term has been used for other diseases across spatial scales; including to designate neighborhoods with more efficient cholera transmission,<sup>27</sup> or countries where a high proportion of tuberculosis cases are multidrug resistant.<sup>28</sup> Often the choice of spatial scale is driven by practical considerations. Data may be only available at one geographic scale,<sup>26–28</sup> or there may be a specific scale at which relevant policies or interventions are implemented. There are other, more principled approaches. Algorithms such as SaTScan use statistical approaches to identify the spatial extent of hotspots.<sup>29</sup> Bousema and others used

\*Address correspondence to Justin Lessler, Department of Epidemiology, Johns Hopkins University, 615 North Wolfe Street, E6545, Baltimore, MD 21205. E-mail: justin@jhu.edu

†These authors contributed equally to this work.

disease biology to describe their geographic scale, defining malaria hotspots as areas smaller than the dispersal range of vector mosquitoes where the basic reproductive number ( $R_0$ ) is higher than surrounding areas.<sup>2</sup>

The difference between hotspots as areas of elevated incidence or prevalence versus elevated transmission efficiency is subtle but important. Whether the two measures lead us to identify the same areas as hotspots depends on the disease and how incidence and prevalence are measured. For instance, frequent malaria infection reduces the severity of infections<sup>30</sup> so an area with intermittent transmission could have more symptomatic cases than one with frequent transmission.<sup>24</sup> However, if incidence is measured based on the frequency of asymptomatic parasitaemia,<sup>23</sup> or symptomatic infection in young (and more likely previously uninfected) children,<sup>25</sup> then high incidence areas should also correspond to areas of elevated transmission. Depending on the timescale, similarly counterintuitive results may occur when comparing the distribution of disease in endemic and epidemic contexts. For example, cholera generally transmits with higher efficiency in Bangladesh than in Zimbabwe, which experiences epidemics every 3–5 years. However, if one were to look only at overall incidence of cholera between those two countries in 2008–2009, one might be led to erroneously conclude that Zimbabwe was more of a cholera hotspot due to the large epidemic that occurred that year.<sup>31</sup> Hotspots as areas of elevated transmission intensity have received attention because more efficient control may be achieved by targeting these areas,<sup>2,3</sup> especially if a single area appears to sustain transmission.<sup>24</sup> For example, this has been promoted as one potential approach for the optimal employment of limited oral cholera vaccine supplies.<sup>27</sup> Various factors have been shown to create transmission hotspots, including overcrowding,<sup>32</sup> poverty,<sup>33</sup> lack of adequate water, sanitation, and hygiene infrastructure,<sup>34</sup> and geographic clusters of “core groups” that drive the transmission of STIs.<sup>35</sup> Features that define the hotspot will dictate the development of appropriate control measures. The implications of such heterogeneous underpinnings of transmission provide a further argument for clarity, as the misspecification of hotspots based on differential causes may result in poorly designed, misguided, and potentially costly control efforts or missed opportunities for targeting limited resources.

Still, targeting hotspots is not a panacea for control. In outbreaks, generalized interventions or those targeted at “coldspots” may prove more effective, particularly if implemented late in response to epidemics, since the local epidemics in hotspots may have run their course by the time interventions can be put in place.<sup>36</sup> Preventive

vaccination strategies targeting hotspots may also be suboptimal if an intervention (e.g., vaccine) efficacy is incomplete and the transmission efficiency in the hotspot is sufficiently high so that even with high intervention coverage, close to 100% of the population will ultimately be infected in the hotspot.<sup>36,37</sup> Even with a proactive strategy and a nonleaky vaccine, the benefits could be larger in nonhotspot areas if transmission can be interrupted in these areas but not in hotspots (i.e., the reproductive number cannot be driven below one in the hotspot but can elsewhere).

#### AREAS FREQUENT FOR DISEASE EMERGENCE OR REEMERGENCE

Hotspot can also refer to an area with a high risk for infectious disease emergence or reemergence. This common usage has captured the public’s imagination in books such as *The Hot Zone*.<sup>38</sup> Its origins are in ecology, where “hotspot” describes an area of high biodiversity.<sup>39</sup> Hotspots of disease emergence are usually designated on broader spatial scales than those of elevated prevalence or transmission: southeast Asia is often referred to as an emerging infectious disease hotspot,<sup>40</sup> as is West Africa,<sup>41</sup> or even the entire African continent.<sup>42</sup> While there have been attempts to map disease emergence at finer spatial scales,<sup>43</sup> the goal has not necessarily been to identify highly localized disease emergence hotspots. Critical to defining emergence hotspots is the definition and identification of emergence events. Jones and others defined an emergence event as the first reported case of a new infectious disease in a human population.<sup>43</sup> Others have considered each separate spillover event or zoonotic disease outbreak as an emergence,<sup>42</sup> while others also include the foci of reemerging diseases such as cholera, yellow fever, and typhoid as hotspots.<sup>44</sup>

#### TEMPORAL AND SPATIAL CHARACTERISTICS OF HOTSPOTS

Hotspots of any type do not necessarily remain stable over time, but their temporal characteristics are rarely discussed. Exceptions include Bejon and others,<sup>23</sup> who showed that some groups of homesteads in rural Kenya remain malaria transmission hotspots for years, whereas others, particularly those identified based on febrile malaria rather than parasitemia, lasted only months. Understanding the stability of hotspots over time is crucial for guiding disease-control strategies, otherwise we may end up chasing one former hotspot after the next, missing the true high risk areas.

TABLE 1  
Overview of definitions for different types of “hotspots”

Definition	References	Suggested term and alternatives
An area of elevated transmission efficiency (i.e., elevated reproductive number, $R$ )	2,3,27,36	Transmission hotspot, transmission foci
An area with a high frequency of emergence or reemergence of diseases or drug-resistant strains.	40–44	Emergence hotspot
An area of elevated disease incidence or prevalence or a geographic cluster of cases	23,24,26,28	Burden hotspot, high burden country/province/and so on, hyperendemic region, case cluster

## CONCLUSION

Hotspot is an evocative term that is often used in a casual and imprecise manner to spark interest in a paper or topic. Recently, the term has found increased use in policy and practice documents,<sup>6–8,45</sup> guiding decisions on resource allocation and disease-control strategies. Although in some documents “hotspot” has a more specific definition (e.g., U.S. President’s Malaria Initiative 2013<sup>7</sup>), others use the term with little clarification. Given the multiplicity of meanings, it may be best to forgo using this evocative term and use a more well-defined synonymous term instead. In many cases, alternative terms are more precisely defined in policy documents, such as malaria transmission foci<sup>46</sup> or HIV-hyperendemic countries.<sup>47</sup> However, when hotspot is used, we suggest that such uses require a more descriptive explanation of the criteria by which that hotspot is defined to prevent misinterpretation and confusion.

We recommend that the meaning of a “hotspot” be made explicit by use of an appropriate modifier such as: “burden hotspot,” to denote areas of elevated disease prevalence or incidence; “transmission” or “risk hotspot,” to denote areas of elevated transmission efficiency or a higher risk of disease acquisition; and “emergence hotspot,” to denote areas with an increased probability of disease emergence or reemergence. Furthermore, when geographic scale is important, a precise, data-based definition of spatial extent and characteristics should be provided. Table 1 provides a summary of the various definitions of hotspot common in the literature, key citations, and suggested alternative or clarifying terms to reduce the risk of confusion and simplify policy recommendations.

Spatial heterogeneity in disease processes is a growing field of study. The identification of hotspots of all types can play an important role in research, policy, and practice, particularly in resource planning, allocation, and implementation in response to infectious diseases. However, public health, like all fields, is subject to fads in concepts and terminology. Hotspot is an evocative term for important concepts, but a useful term should not be rendered useless by imprecision or overuse. Policy makers and public health researchers should be sensitive to its multitude of uses within the health sciences, and take care in their own use of the term.

Received May 26, 2016. Accepted for publication February 26, 2017.

Published online April 24, 2017.

Acknowledgments: We would like to thank Didier Bompangue and the attendees of the Kinshasa Cholera Round Table for the discussions that motivated this work.

Authors’ addresses: Justin Lessler, Heather S. McKay, and Sean M. Moore, Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, E-mails: justin@jhu.edu, hmckay4@jhu.edu, and mooresea@gmail.com. Andrew S. Azman, Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, and Medecins Sans Frontieres, Geneva, Switzerland, E-mail: azman@jhu.edu.

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

## REFERENCES

- Hotez PJ, 2014. Ten global “hotspots” for the neglected tropical diseases. *PLoS Negl Trop Dis* 8: e2496.
- Bousema T, Griffin JT, Sauerwein RW, Smith DL, Churcher TS, Takken W, Ghani A, Drakeley C, Gosling R, 2012. Hitting hotspots: spatial targeting of malaria for control and elimination. *PLoS Med* 9: e1001165.
- Dowdy DW, Golub JE, Chaisson RE, Saraceni V, 2012. Heterogeneity in tuberculosis transmission and the role of geographic hotspots in propagating epidemics. *Proc Natl Acad Sci USA* 109: 9557–9562.
- UNAIDS Reference Group on Estimates Modelling and Projections, 2013. *Identifying Populations at Greatest Risk of Infection: Geographic Hotspots and Key Populations*, 25–26.
- U.S. President’s Emergency Plan for AIDS Relief, PEPFAR 3.0, 2014 *Controlling the Epidemic: Delivering on the Promise of an AIDS-Free Generation*, 32. Available: <http://www.pepfar.gov/documents/organization/234744.pdf>. Accessed March 1, 2015.
- World Health Organization, Government of Guinea, Government of Liberia, Government of Sierra Leone, 2014. *WHO Strategic Action Plan for Ebola Outbreak Response*. Available at: <http://www.who.int/csr/disease/ebola/evd-outbreak-response-plan-west-africa-2014-annex1.pdf>. Accessed March 1, 2015.
- President’s Malaria Initiative, 2013. *Tanzania Malaria Operational Plan FY 2014*. Available at: [http://www.pmi.gov/docs/default-source/default-document-library/malaria-operational-plans/fy14/tanzania\\_mop\\_fy14.pdf?sfvrsn=10](http://www.pmi.gov/docs/default-source/default-document-library/malaria-operational-plans/fy14/tanzania_mop_fy14.pdf?sfvrsn=10). Accessed March 1, 2015.
- United States Agency for International Development, *EMERGING Pandemic Threats Program Summary*. 2014. Available at: <https://scms.usaid.gov/sites/default/files/documents/1864/EPT2-Narrative-508.pdf>.
- Hempel C, Quinn J, 1848. *Jahr’s New Manual or Symptomen Codex*. Willam Radde, New York.
- Prabhakar HB, Sahani DV, Fischman AJ, Mueller PR, Blake MA, 2017. Bowel hot spots at PET-CT. *Radiographics* 27: 145–159.
- Bulte JWM, 2005. Hot spot MRI emerges from the background. *Nat Biotechnol* 23: 945–946.
- Park B-J, Lord D, Lee C, 2014. Finite mixture modeling for vehicle crash data with application to hotspot identification. *Accid Anal Prev Elsevier Ltd* 71: 319–326.
- Yang T-C, McManus B, 2010. Infant Mortality and Social Environment in Georgia: An application of hotspot detection and prioritization. *Environ Ecol Stat* 17: 455–471.
- Wilhelm M, Eberwein G, Hölzer J, Gladtko D, Angerer J, Marczyński B, Behrendt H, Ring J, Sugiri D, Ranft U, 2007. Influence of industrial sources on children’s health—hot spot studies in North Rhine Westphalia, Germany. *Int J Hyg Environ Health* 210: 591–599.
- Cox GR, Owens C, Robinson J, Nicholas A, Lockley A, Williamson M, Cheung YT, Pirkis J, 2013. Interventions to reduce suicides at suicide hotspots: a systematic review. *BMC Public Health* 13: 214.
- Fang Z, Kulldorff M, Gregorio DI, 2004. Brain cancer mortality in the United States, 1986 to 1995: a geographic analysis. *Neuro-oncol* 6: 179–187.
- Short MB, Brantingham PJ, Bertozzi AL, Tita GE, 2010. Dissipation and displacement of hotspots in reaction-diffusion models of crime. *Proc Natl Acad Sci USA* 107: 3961–3965.
- Orgel A, Orgel LE, 1965. Induction of mutations in bacteriophage T4 with divalent manganese. *J Mol Biol* 14: 453–457. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/5880862>. Accessed February 10, 2015.
- Dixit A, Yi L, Gowthaman R, Torkamani A, Schork NJ, Verkhivker GM, 2009. Sequence and structure signatures of cancer mutation hotspots in protein kinases. *PLoS One* 4: e7485.
- Ma K, Qiu L, Mrasek K, Zhang J, Liehr T, Quintana LG, Li Z, 2012. Common fragile sites: genomic hotspots of DNA damage and carcinogenesis. *Int J Mol Sci* 13: 11974–11999.

21. Liu Z, Luo K, He H, Hou J, 2005. Hot-spot mutations in hepatitis B virus core gene: eliciting or evading immune clearance? *J Viral Hepat* 12: 146–153.
22. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, Daszak F, 2008. Global trends in emerging infectious diseases. *Nature* 451: 990–993.
23. Bejon P, Williams TN, Liljander A, Noor AM, Wambua J, Ogada E, Olotu A, Osier FH, Hay SI, Färnert A, Marsh K, 2010. Stable and unstable malaria hotspots in longitudinal cohort studies in Kenya. *PLoS Med* 7: e1000304.
24. Ernst KC, Adoka SO, Kowuor DO, Wilson ML, John CC, 2006. Malaria hotspot areas in a highland Kenya site are consistent in epidemic and non-epidemic years and are associated with ecological factors. *Malar J* 5: 78.
25. Bousema T, Drakeley C, Gesase S, Hashim R, Magesa S, Mosha F, Otieno S, Carneiro I, Cox J, Msuya E, Kleinschmidt I, Maxwell C, Greenwood B, Riley E, Sauerwein R, Chandramohan D, Gosling R, 2010. Identification of hot spots of malaria transmission for targeted malaria control. *J Infect Dis* 201: 1764–1774.
26. Srivastava A, Nagpal BN, Joshi PL, Paliwal JC, Dash AP, 2009. Identification of malaria hot spots for focused intervention in tribal state of India: a GIS based approach. *Int J Health Geogr* 8: 30.
27. Azman AS, Luquero FJ, Rodrigues A, Palma PP, Grais RF, Banga CN, Grenfell BT, Lessler J, 2012. Urban cholera transmission hotspots and their implications for reactive vaccination: evidence from Bissau City, Guinea Bissau. *PLoS Negl Trop Dis* 6: e1901.
28. Becerra MC, Bayona J, Freeman J, Farmer PE, Kim JY, 2000. Redefining MDR-TB transmission “hot spots.” *Int J Tuberc Lung Dis* 4: 387–394.
29. Kulldorff M, 1997. A spatial scan statistic. *Commun Stat Methods* 26: 1481–1496.
30. Reyburn H, Mbatia R, Drakeley C, Bruce J, Carneiro I, Olomi R, Cox J, Nkya WM, Lemnge M, Greenwood BM, Riley EM, 2005. Association of transmission intensity and age with clinical manifestations and case fatality of severe *Plasmodium falciparum* malaria. *JAMA* 293: 1461–1470.
31. Mukandavire Z, Liao S, Wang J, Gaff H, Smith DL, Morris JG, 2011. Estimating the reproductive numbers for the 2008–2009 cholera outbreaks in Zimbabwe. *Proc Natl Acad Sci USA* 108: 8767–8772.
32. Munch Z, Van Lill SW, Booysen CN, Zietsman HL, Enarson DA, Beyers N, 2003. Tuberculosis transmission patterns in a high-incidence area: a spatial analysis. *Int J Tuberc Lung Dis* 7: 271–277.
33. Spence DP, Hotchkiss J, Williams CS, Davies PD, 1993. Tuberculosis and poverty. *BMJ* 307: 759–761.
34. Yang K, LeJeune J, Alsdorf D, Lu B, Shum CK, Liang S, 2012. Global distribution of outbreaks of water-associated infectious diseases. *PLoS Neglected Trop Dis* 6: e1483.
35. Thomas JC, Tucker MJ, 1996. The development and use of the concept of a sexually transmitted disease core. *J Infect Dis* 174 (Suppl 2): 134–143.
36. Azman AS, Lessler J, 2015. Reactive vaccination in the presence of disease hotspots. *Proc Biol Sci* 282: 20141341. Available at: <http://dx.doi.org/10.1098/rspb.2014.1341>. Accessed February 15, 2015.
37. Wu JT, Peak CM, Leung GM, Lipsitch M, 2016. Fractional dosing of yellow fever vaccine to extend supply: a modelling study. *Lancet* 388: 2904–2911.
38. Richard Preston, 1995. *The Hot Zone*. United States.
39. Myers N, Mittermeier R, 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. Available at: <http://www.nature.com/articles/35002501>. Accessed March 5, 2015.
40. Horby PW, Pfeiffer D, Oshitani H, 2013. Prospects for emerging infections in east and southeast Asia 10 years after severe acute respiratory syndrome. *Emerg Infect Dis* 19: 853–860.
41. Pedersen AB, Davies TJ, 2009. Cross-species pathogen transmission and disease emergence in primates. *EcoHealth* 6: 496–508.
42. Chan EH, Brewer TF, Madoff LC, Pollack MP, Sonricker AL, Keller M, Freifeld CC, Blench M, Mawudeku A, Brownstein JS, 2010. Global capacity for emerging infectious disease detection. *Proc Natl Acad Sci USA* 107: 21701–21706.
43. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, Daszak P, 2008. Global trends in emerging infectious diseases. *Nature* 451: 990–993.
44. Heymann DL, Rodier GR, Support O, Alert O, 2001. Hot spots in a wired world: WHO surveillance of emerging and re-emerging infectious diseases. *Lancet Infect Dis* 1: 345–353.
45. National AIDS Control Organization, 2007. *Targeted Interventions Under NACP III: Operational Guidelines; Volume I Core High Risk Groups*. Available at: <http://naco.gov.in/sites/default/files/NACP-III.pdf>. Accessed March 22, 2015.
46. World Health Organization Regional Office for the Eastern Mediterranean, 2007. *EMRO Technical Publications Series 33: Guidelines on the Elimination of Residual Foci of Malaria Transmission*. Cairo, Egypt: World Health Organization. Available at: <http://applications.emro.who.int/dsaf/dsa742.pdf>. Accessed March 22, 2015.
47. United States Agency for International Development, 2008. *Report on the Global AIDS Epidemic*. Available at: [http://data.unaids.org/pub/GlobalReport/2008/jc1510\\_2008global\\_report\\_en.pdf](http://data.unaids.org/pub/GlobalReport/2008/jc1510_2008global_report_en.pdf). Accessed March 22, 2015.