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Markets and Mutations: mosquito nets and the politics of disentanglement in global health

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ABSTRACT

Malaria management involves the continuous calibration of micro-environments, namely of the entangled habitats of mosquitoes, parasites and humans. This article focuses on humans and mosquitoes as unruly actors of environmental management. Drawing on economic sociology, I show how framing mosquito nets as 'humanitarian goods' disentangles particular economic and ecological realities. Juxtaposing politico-economic processes of mosquito net production and distribution with the emergence of insecticide resistance in mosquitoes I show how their disentanglement creates unintended social and disease realities. This suggests rethinking the spatio-temporal politics of environmental management of mosquitoes and malaria, and nuances the patterns of how exactly humanitarian goods 'do good'.

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1. Introduction

Mosquitoes have difficulties to qualify as companion species for humans (Haraway, 2008; Beisel, 2010a,b). Inflicting itch and capable of transmitting deadly infectious diseases, mosquitoes and their habitat have for centuries been objects of environmental management (e.g. Mitchell, 2002; Packard, 2007; Ross, 1902; Russel, 1955). This paper contributes to this special issue on environmental management by interrogating mosquito nets as a global health tool that separates humans from unwanted entanglements with mosquitoes and parasites. Recent scholarship in geography, anthropology and cognate disciplines has emphasised the more-than-human or multispecies character of biosocial life (Whatmore, 2002; Hinchliffe, 2007; Kirksey and Helmreich, 2010). In this way of thinking human, animal and plant life is not neatly divided up in human on the one hand, and natural on the other. Rather the focus of analysis is on the interwovenness, or the "material-semiotic knottings" of humans with other forms of life – understanding for instance dogs and humans as companion species, and bacteria as constituents of human bodies (Haraway, 2008). While the initial focus was on the moments "when species meet" (Haraway) or on tracing non-human "presences" in urban centres (Hinchliffe et al., 2005), more recent academic work has turned its attention to more troubled forms of multispecies coexistence: focusing on dangerous encounters between humans and wolfs (Buller, 2008), humans and cougars (Collard, 2012), the "volatile ecologies" that bind humans, elephants and alcohol together (Barua, 2013), or on "inhuman nature" and its disasters (Clark, 2011), such as tsunamis (Tironi and Farías, 2015). But it does not need overtly aggressive animals or exuberant physical forces to create uncomfortable human–nonhuman entanglements, more-than-human relations with more harmless or less visibly aggressive creatures can be "awkward" too (Ginn et al., 2014; Beisel et al., 2013). As Nading shows *Aedes* mosquitoes, humans and the dengue virus are deeply entangled with "changes in bodies reverberate through landscapes, and vice versa" (Nading, 2014: 10). But in the case of dangerous diseases or slimy slugs it is not only attachment that matters, rather entanglement and detachment go together. Examining the sticky lives of slugs and gardeners Ginn foregrounds practices of detachment in more-than-human relations characterised by disgust and violence (Ginn, 2014, see also Candea, 2010). Similarly, Kelly and Lezaun characterise malaria control as a task of "laborious disentanglement" of mosquitoes, humans and parasites describing how politics and practices of separation relate to urban maintenance and the management of environments more broadly (Kelly and Lezaun, 2014).

My article is situated in this literature and an ethos of multispecies entanglements, but concerned with a different politics of disentanglement. Drawing on economic sociology (Callon, 1998, 2007; Çalışkan and Callon, 2009, 2010), I analyse the management of malaria by juxtaposing politico-economic processes of mosquito net production and distribution with the emergence of insecticide resistance in mosquitoes. In this I am interested how framing of

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mosquito nets as "humanitarian goods" (Redfield, 2012) entangles them into particular markets and logics, and disentangles them from others (Callon, 1998). I carve out the ways in which dominant logics in global health and malaria control obscure local economic practices and downplay the importance of shifting ecologies. I emphasise the effects that particular framings of mosquito nets have for situated practices of environmental management (Lippert et al., 2015): for humans producing, selling, buying and sleeping under nets, as well as for mosquitoes being repelled or killed by the nets and its enmeshed insecticides.

The first disentangled reality I identify is located in the political economy of mosquito nets. Insecticide-treated nets today are objects of global health, they are meant to preserve the health of populations by establishing a – both manual and chemical – barrier between humans and mosquitoes. In the global health logic it remains secondary how the nets are produced, distributed and who benefits economically from their sale. What is of importance is the capacity of nets to 'save lives', as exemplified in an ad of the charity Nothing but Nets: "Send a Net. Save a Life" (Nothing but Nets, 2015), or in net counts such as the Global Fund's "450 million insecticide-treated nets distributed" (The Global Fund, 2015). I trace how this understanding of nets as a singular object, namely as a humanitarian good, neglects the nets' potential power as an economic object.[1] Nets are manufactured by international companies and not locally where the nets are used. This means international donations of mosquito nets end up mostly benefiting companies from developed countries, conveying only a single benefit to the end-user in developing countries: protection from mosquito bites. Not casting the economic value of nets as a resource I suggest is a missed opportunity and has (unwanted) side effects: the introduction of insecticide-treated nets has put people out of work in Ghana, where the sewing of mosquito nets used to be an income source for tailors.[2] This invisibility can be read as – what economists characterise as 'negative externality', a "disentanglement" in Callon's vocabulary (Callon, 1998). I suggest that making such disentangling practices visible enables us to learn valuing nets as a tool of global health *and* an economic good.

The second disentanglement I discuss also interferes with policies, but rather differently. Mutations, genetic adaptation of mosquitoes to insecticides used in insecticide-treated nets have increasingly been detected in malarious environments on the African continent, and threaten to significantly undermine the effectiveness of nets (WHO, 2012). The insecticide applied on the nets accelerates mutations, it increases selection pressure on the mosquitoes, and thus pushes mosquito populations collectively to adapt their bodies to control interventions. More than simply endangering the effectiveness of one specific disease control technology though, the vitality of mosquitoes threatens malaria vector control more broadly, as not only nets rely on insecticides, but also indoor insecticide spraying of habitations. Taken together these two technologies form the backbone of current mosquito control strategies, resistance could thus have dramatic consequences. Insecticide resistance also points to the limited agency of humans in environmental management. In this sense mosquitoes and their mutating genomes and bodies can be read as a second disentanglement of current environmental management strategies in malaria control. By trying to keep mosquitoes passive, natural and controllable, humans achieve the opposite; mosquitoes assert their vitality and adapt to shifting environments. My analysis of mutating mosquitoes as disentangled from current mosquito net politics I hope serves to underline what Nigel Clark calls the "inhuman" quality of nature (Clark, 2011). It emphasises that mosquitoes are more dynamic than human control efforts reckon with, and that we live on "an earth which does its own thing, whatever surcharge we add to its mobilizations – or to its obduracy" (ibid: 26).

But why combine the political economy and biology of mosquito nets in one paper? Drawing these cases together I suggest enables us to learn more about undesirable effects of policy-making. After all, both cases have in common that they cannot be controlled or harnessed by current malaria management practices. Indeed, as Shaw et al. observe, mosquitoes are an instructive case study into "the impossibility of controlling "life", suggesting that "'monstrosity' [of mosquitoes] arises in the excesses and discontinuities between the mosquito's umwelt and the human efforts that seek to eliminate it" (Shaw et al., 2013: 260). Inspired by recent social studies of science and technology (cf. Law, 2004; Mol, 2003, 2008), I pay attention to the *effects* that escape mosquito management interventions – things that do not seem to fit or do not seem to matter to the problem in question. As we will see, this is an investigation into dominant and alternative logics in global health, and their lived interferences. I use the term 'logic' in the way Annemarie Mol uses it (Mol, 2008); not as a term referring to an encompassing coherence, but to "a local, fragile and yet pertinent coherence" (ibid, p. 8). Within malaria control biomedical concerns can be identified as the dominant logic informing interventions. This logic sees malaria as part of health care provision, and is derived from knowledge produced within the biomedical sciences, a field that has recently reconfigured itself into "that obscure object of global health" (Fassin, 2012). As Fassin argues there is much that might indeed not be new in the shift from international public health to global health. However, for the purpose of this article it is worth emphasising some selected shifts: (i) coming with the entrance of the World Bank into matters of health (through structural adjustment programmes), scholars have documented *a shift towards numerical logics*, comparisons and equivalences made between continents and countries, later epitomised by the Millennium Development Goals (Pfeiffer and Chapmann, 2010; Erikson, 2012). (ii) In combination with this, *a shift towards fragmentation* of actors, a new dominance of public–private initiatives and other parastate actors over national actors (Geissler, 2013, 2015; Rees, 2014), and a move towards 'projects' as units of action has been observed (Whyte et al., 2013; Krause, 2014). (iii) Underlying *is an uneven geography* of "the global health complex" (McGoey et al., 2011): of technology transfer and travelling models (Behrends et al., 2014), of colonial and postcolonial power relations (Keller, 2006), of continued neglect (Kelly and Beisel, 2011) and unequal collaborations and experiments in global health science (Rottenburg, 2009; Crane, 2013; Geissler and Okwaro, 2014).

As Peter Redfield shows these moves have come together with a proliferation of what he calls "humanitarian goods" (Redfield, 2012). Drawing together diverse objects, such as water purification straws (Life Straw), plastic bags meant to substitute toilets (PeePoo bags), and a peanut-paste designed to address malnutrition (Plumpy'Nut), Redfield suggests that these mobile technologies of humanitarian aid and global health have helped form new "bioexpectations", namely the attempt to address the world's most pressing problems not through new regimes of governance, but through the "alchemy of innovative design and empirical monitoring" (ibid: 158). What unites these objects is not only that they are designed to substitute lacking health, sanitation or nutrition infrastructures, but also that they work as goods in humanitarian markets. As such,

[1] I use the term, object' here in the sense actor-network theory and after use it. Objects are understood not as unchangeable material objects, but as the outcomes of socio-material relations (Latour, 2005). As Law and Singleton (2003) put it: "many (probably all) objects putatively located in physical space can only be detected in a network of relations that makes them visible" (Law and Singleton, 2003: 4, emphasis in the original). This underlines the contingent character of objects and makes "ontological politics" an important focus of study (Mol, 1999).

[2] The practice of sowing nets is more wide spread, however I focus on Ghana, as this article draws on ethnographic material collected in Ghana in the course of 9 months of fieldwork in 2007/2008 and 2009/2010.

Redfield argues they "foreground moral and medical rather than market values" (ibid: 159).

My analysis focuses on another one of these humanitarian goods in global health, one that is imbued with many hopes for malaria elimination and development. A good that has for long been the international emblem of malaria prevention: mosquito nets. Under the umbrella of the Millennium Development Goals international organisations have given malaria control renewed priority. In this effort insecticide-treated nets are a key element of malaria control in sub-Saharan Africa. Since the 1990s, mosquito nets are widely impregnated with insecticides and are implemented on a large-scale in sub-Saharan Africa.[3] "Over 142 million (nets) were delivered to countries in sub-Saharan Africa by manufacturers in 2013. (...) Adding these nets to the 70 million delivered in 2012, a cumulative total of 427 million will have been delivered to countries in sub-Saharan Africa between 2012 and 2014 (WHO, 2014: 12). WHO estimates that the proportion of households that own at least one insecticide-treated mosquito net in sub-Saharan Africa has increased from 3% in 2004 to 49% in 2013, with an estimated 44% of the population sleeping under a net in 2013, compared to 2% in 2004 (WHO, 2014: 10). Insecticide-treated nets are believed to have contributed substantively to reductions of malaria, and are widely recognised as the most cost-effective malaria control tool.

Focusing on mosquito nets and their effects on local economies and ecologies, I provide an ethnographic account of what the proliferation of a global health logic, or as Redfield puts it, the foregrounding of moral and medical values (see above, Redfield, 2012), might render invisible or neglect (Kelly and Beisel, 2011). I suggest framing the potential of mosquito nets in terms of 'nets distributed, lives saved' renders economic and ecological consequences of mosquito nets a "hinterland" (Law, 2004). Law proposes that when one logic is dominant in the assemblage of relations that make up an object, certain practices become influential or common sense while others escape, are too small to matter. These form part of "a hinterland of indefinite, necessary, but hidden Otherness" (ibid: 14). Economic theory describes such effects as 'negative externalities', as unwanted side effects that can be remedied once recognised. Callon takes issue with this optimistic notion of controllability, and argues that any total framing is impossible and remedying externalities creates new "overflows" or "disentanglements" (Callon, 1998). He instead proposes to focus on "processes of economization", on the practices of "framing" that occur in the socio-economic constitution of "calculative agency" (Callon, 2007; Çalışkan and Callon, 2010). In other words, Callon invites us to investigate economic practices and objects performatively, he urges us to pay attention to what a logic entangles (or internalises) and disentangles (or externalises). This he suggests gives us insights into the patterning, or "scaping" of inclusion and exclusion (Lippert, 2015), and ultimately the creation of inequalities through processes of economization. My analysis of mosquito nets as humanitarian goods takes these insights as a starting point, since as Cross (2013) reminds us, many humanitarian goods today are also commodities, they "construct a market and make this market a space of humanitarian practice" (Cross, 2013: 19). This market includes not only producers, donors and end-users, but as Cross shows also venture capital funds and social investment companies (ibid: 7). This analysis shares the interest in how humanitarian goods are *made* with Cross, however my main focus is on the end-users – humans and mosquitoes. In what follows I trace the effects of the conditions of production of mosquito nets on local economies, as well as the ecological consequences of nets that are bracketed out of much of their existence as humanitarian goods. I suggest that looking closely at what humanitarian goods might neglect by being construed as moral and medical objects, nuances the patterns of how humanitarian goods 'do good'.

2. Mosquito net markets

1 Net. 10 Bucks. Save Lives (Spread the Net Campaign)
Send a Net. Save a Life. (Nothing but Nets Campaign)
Nets for Life. (Nets for Life Campaign)

Insecticide-treated nets are a popular charity object: one net can be delivered to a family in need for US$ 10, meaning with a small contribution donors can have tangible effects and 'save a life' (Nothing but Nets, 2009). The connection between providing a mosquito net and saving a life is direct and compelling in its simplicity. This is used in marketing: "This Christmas, for just 10 bucks you can buy perhaps the most gratifying present you'll ever give: an insecticide-treated mosquito bed-net that will save a vulnerable child's life in Africa" (SFU, 2008, no page number). Rooted in a long legacy of missionary colonialism that brings together Christianity, commerce and civilization (Guha, 1997, quoting Bonner 1994), mosquito nets catapult poor and suffering African children right under the christmas tree. Generally speaking, the non-governmental advocacy/charity sector has formed a close alliance with politicians and celebrities, and mosquito net charity flourishes – as one Ghanaian entomologist put it: "they are flooding Africa with mosquito nets". But crucially, in the long run, these actors are also doing something else: they are creating a market, a market where multinational capitalist business rules apply, albeit with specific humanitarian industry characteristics. For a start, in mosquito net markets big international donors are the buyers, not individual end users. The dominant net procurement agency worldwide is UNICEF, the number one customer for insecticide-treated nets. The nets are mainly financed through country grants from the Global Fund or other donor agencies, such as The World Bank's *Malaria Booster Program* or the British development agency DFID.

But not every mosquito net brand can be purchased by those donor agencies: The WHO via its *Pesticide Evaluation Scheme* (WHOPES) certifies net producers that adhere to their safety and quality standards (www.who.int/whopes). WHOPES "promotes and coordinates the testing and evaluation of pesticides for global health" (ibid), and the WHOPES recommendation system is linked to procurement. UN (-related) organisations for instance will only be able to procure recommended nets. In practice the WHOPES-procedure excludes small local producers, not because their products are of lesser quality, but because most small companies are not able to afford the licensing process. As NetMark, a social marketing initiative funded by US AID, has put the problems for African manufacturers: "Many countries would like to develop their own net production capacity, however, net manufacturing requires millions of dollars in investment in an area of high competition and low margins" (NetMark, n.d.).

Once the nets are manufactured the nets have to be brought to the end-users. In 2007 in Ghana the main actors with respect to mosquito net implementation were the Ghana Health Service and UNICEF, who together run a free distribution of nets to vulnerable groups at the *National Integrated Maternal and Child Health Care Campaign*. Executed across the country on three days in November, the campaign provided 1.5 million nets for free to

[3] In the early 1990s one publication claimed that insecticide-treated nets provide a 42% decrease in child mortality (Alonso et al., 1991). This spectacular result prompted the WHO research unit TDR to commission a large-scale four-country study into the impact of insecticide-treated nets (in The Gambia, Ghana, Kenya and Burkina Faso). The positive results of these studies then triggered the policy shift aimed at universal coverage of insecticide-treated nets in malarious areas (Binka et al., 1996; D'Alessandro et al., 1995; Nevill et al., 1996).

children between 0 and 11 months and pregnant women.[4] The nets for the campaign were financed by international donors, namely *The World Bank*, *UK's Department for International Development* and *Japan International Cooperation Agency*. In recent years the integrated campaign was not repeated, nets were nevertheless distributed in high numbers in similar fashion. Generally, the distribution of nets is an integral part of routine malaria control, and – as we can see in the 2007 campaign – also reflects the priorities of international donors. The distribution of free nets is strategically targeted at vulnerable groups, namely pregnant women and children under five. It thus only caters to a specific segment of the population.

To make insecticide-treated nets available to the general public is the work of yet other organisations. From 1999–2009 the social marketing initiative NetMark aimed to make insecticide-treated nets commercially available in sub-Saharan Africa. NetMark was founded by the American development agency US AID, and was active in eight African countries; Ghana was one of them. NetMark aimed to "reduce the burden of malaria in sub-Saharan Africa by increasing the commercial supply of and public demand for insecticide treated nets" (NetMark Website, 2007). They worked with commercial partners as well as the Ghanaian National Malaria Control Programme in order to create a market for insecticide-treated nets. In Ghana they *inter alia* run a voucher system, where pregnant mothers attending antenatal care got counselling on insecticide-treated nets and a voucher, which was supposed to enable them to buy insecticide-treated nets for approximately half of the market prize from commercial outlets. NetMark's role was to organise the commercial partners, and make sure that outlets selling insecticide-treated nets are widely spread throughout the country. While NetMark also worked with clinics and other global health institutions, the initiative was predominately concerned with building a commercial mosquito net market. In 2007, a coordinator at the National Malaria Control Programme explained to me that NetMark is valuable to them because of potential donor fatigue. She argued that through the help of NetMark, Ghana would soon have an established commercial distribution system in the towns and villages in case donors get tired of funding and distributing nets. Interestingly my interviewee considered the commercial system more sustainable when compared to a global health system, whose capacity entirely depends on donors: "NetMark is a way to keep the [commercial] partners on board", she says, "especially considering that donations of insecticide-treated nets are often a marketing strategy, which will not happen endlessly". Many global health specialists disagree; they argue that nets should be free and only distributed through public channels in order to ensure universal coverage and usage.

> "Tragically, funds mobilised for malaria prevention and control are not used for saving lives, but are instead diverted to try to create new markets for mosquito nets that do not exist. This approach has compromised the effectiveness of malaria control efforts. We strongly suggest that malaria-endemic countries and donor agencies should abandon the idea of social marketing, especially in rural areas greatly affected by malaria, and also in urban areas with malaria transmission"
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> [Teklehaimanot et al., 2007, p. 2146.]

The argument is that no market for mosquito nets exists, because people cannot afford them and in order to bring the nets to the people and have a measurable effect on malaria case numbers, nets need to be free. The assertion that social marketing is trying to "create new markets for mosquito nets that do not exist" is right in the sense that many people are not able to pay. However, it is also wrong, because actually those markets have already existed before social marketing or even before insecticide-treated donor nets, as an excerpt from my field diary shows:

> *February 2009, London*
>
> *I meet my Ghanaian friend Daniel at the British Library for a coffee. As usual we start to talk about malaria. (. . .) After some time Daniel tells me a family story: He says his mother used to make mosquito nets in Tamale and sell them there. It turns out that not only his mum was doing it, but also many other people in Tamale. This was a local business and well established, it had its own local economy. Daniel characterised the local economy to me as follows: The materials would arrive from Europe, together with used clothes. Netting material arrives in big bales, some of them were of bigger net structure, which was used for clothes and curtains. The ones with finer netting were used for mosquito nets. The material would go to a tailor, who sews nets out of the raw material. Daniel says that this tailoring branch had its very own characteristics, the tailors were usually men rather than women, who mostly do the clothes tailoring. And then the nets go to local distributors, either to people selling the nets on the market, or to people, who would carry the nets into the rural areas, where they sell them to farmers. And this was not a small informal side income for some people, but was an established local economic production and trade network in its own right. The sales were good, albeit seasonal, especially high in the rainy and harvesting seasons, when mosquitoes are abundant and people also have money to buy the nets.*

There is an irony arising here, when one considers that NetMark was working hard to build a market that already existed. However, at closer look the mosquito net market turns out to be two markets. NetMark works to integrate insecticide-treated nets into the Ghanaian market, bringing the price for insecticide-treated nets down through lower taxes, vouchers, and more products in circulation. NetMark aims to build a market for *imported* insecticide-treated nets rather than working with the local *informal sewing market* that Daniel introduced me to. Thus, existing local capacity is not relevant to NetMark, the ugly side-effect of the penetration of international insecticide-treated nets into the Ghanaian market was that many local mosquito net producers lost their income – we can see here an erasing of local practices and networks in the name of development and global health. This is of course by no means a new phenomenon, but in fact has long been deconstructed in critiques of development initiatives (cf Escobar, 1995; Scott, 1998; Rottenburg, 2002). Nevertheless, these established critiques of development still ring true for the case of insecticide-treated nets, and this prompts the question if we still imagine Africa to be an empty continent, rich in resources but without valuable social structures, trade networks and economies? In order to overcome this colonialist attitude, one would need to work with and not parallel to existing local structures in the production, distribution and marketization of mosquito nets. But in the creation of a mosquito net market the rhetoric of global health need, charity and efficiency come together, and as a result international markets get prioritised over local development.

In her book *Dead Aid* (2009) Dambisa Moyo identified the same dilemma. Her solution are micro-credit initiatives that build on, and foster, local economic development (ibid, p. 130-1). This is an important point, and something that is lacking not only when

[4] In addition to polio vaccination for children between 0 and 59 months, de-worming for children between 2 and 5 years old, Vitamin A for 6–59 months old children and new mothers (until 8 weeks after delivery). The campaign also offered a free *National Health Insurance Scheme* registration for children under the age of one.

it comes to mosquito nets but for many services on the African continent.[5] However, looking at the specifics of mosquito nets and malaria control a little closer shows that this might be more complex as one first might assume. Firstly, mosquito nets today are hi-tech products impregnated with insecticides. The newest version of nets called long-lasting insecticide-treated nets (LLINs) have insecticides woven into the fibres of the net, and the insecticide remains effective for the expected lifespan of the net, approximately 4–5 years.[6] The production of ITN/LLINs is factory-based, and involves much more than sewing of meshed materials into nets. This not only renders manufacturing into an expensive, industrial process, but also makes it necessary to have security and quality standards for the use of insecticides. So, even if the donor community was ready to invest into local mosquito net production, it would not be possible to have ITN/LLINs produced in the way that Daniel's mum has done it so far. Most of the ITN/LLIN producers today do not manufacture on the African continent; *Sumitomo Chemicals* was the first ITN producer manufacturing in Africa. *Sumitomo* is committed to manufacturing in Africa and advertises their nets as "Made in Africa, by Africans, for Africans" – 'owned by Japanese' one wants to add though. Their biggest competitor, *Vestergaard-Frandsen*, produces its *Permanet* in Vietnam and Thailand.[7] Thus, while it might not be possible to produce insecticide-treated nets in the way nets used to be produced in Ghana, it would definitely be possible to produce more nets on the African continent, or better even in the countries they are being used.

This section argues that mosquito nets are produced and implemented following a global health *logic*, where only the use of nets for malaria prevention is considered. While the global health argument that mosquito nets should be delivered free of charge to everyone in need has merit in principle, it runs into difficulties in practice. Firstly, it overlooks the post/neocolonial dimensions of the debate, namely that Ghanaians might value the ability to build structures that will make the country more independent from donors. Secondly, it assumes that there is enough money and international political will to sustain the funds needed to provide every one of the billion people living on the African continent, notwithstanding people in malaria risk areas in Asia and Southern America, with insecticide-treated nets. It is estimated that 150 million nets are needed every year to supply all persons at risk of malaria with nets in sub-Saharan Africa (WHO, 2013). However, the World Malaria Report 2013 points out that the international and domestic funding for malaria control in 2012 was substantially less than the resources needed. In terms of mosquito nets, from 2002 until 2010 the disbursement of nets rose significantly from 6 million to 145 million, but fell to 92 million in 2011, and 70 million in 2012. Numbers increased again to an estimated 136 million in 2013 (WHO, 2013, p. ix–x), a total of 214 million are projected to be delivered in 2014 (WHO, 2014, p.12), but the long-term prospect remains unclear. If international donor funding decreases or prioritises other diseases or control strategies, less nets will be available locally.

Thus, my interviewee from the National Malaria Control Programme is rightly concerned about the economic sustainability of relying on donor money. Dambisa Moyo also has a point when she argues that we need to work with, and not parallel to, existing structures if we are to enable economic development in sub-Saharan Africa. She is also right that in mosquito net policies today international markets get prioritised over local development. And, as we have seen above, global health concerns are employed to justify such politics.

With Callon we can understand this as a disentanglement of mosquito nets through its economic valuation as humanitarian goods of global health (Callon, 1998). Seeing insecticide-treated nets not as an item of economic value, but framing it as a global health tool, masks the politics of the market that are going on with and around mosquito nets. By considering local economies as unrelated to the health objectives of the nets, international donor initiatives end up marginalizing local economies. In Ghana, this has resulted in the creation of a parallel market structure that competes with older ways of organising mosquito net production, purchase and delivery. Through stories as the one Daniel told me, the overflows and negative effects of the ways in which mosquito net production and delivery is organised becomes visible – the logic of global health and the politics of markets clash or interfere with each other. However, those different logics do not clash in health policy debates, local economic politics do not play a significant role in insecticide-treated net policies. They are not visible in global health discourses, policies and regulations – they escape.

3. Mutating mosquitoes

This section of the paper stays with mosquito nets, but zooms in on a second overflow of dominant mosquito net framings and practices. In what follows I discuss insecticide use in mosquito nets and its effects on mosquitoes and mosquito bodies as a second disentangled reality of mosquito nets. The analytical focus on insecticides is inspired by a body of scholarly work on pesticide use in agriculture and pest control (cf. Shiva, 1991, 1993; Magdoff et al., 2000; Harrison, 2011). However, while these authors focus on the harmful effects of pesticide use for humans and environment my focus here is on the 'response' of mosquitoes and their bodily configurations to their encounter with pesticides. 'Response' is used in accordance with Donna Haraway to highlight the vitality of agency of mosquitoes, to underline their capacity to respond (Haraway, 2008; see also Beisel, 2010a). I think of mosquitoes not just as 'damaged' through pesticides, but as mutating, changing, escaping the reach of pesticides and malaria control strategies. Following Callon (1998, 2007), mosquito bodies and their genetic and behavioural mutations can be read as a second disentanglement, or negative externality, of the moral economy of humanitarian goods. However, in distinction to the first disentanglement, this externality is not only produced by humans, rather mosquito bodies *actively* disentangle themselves from the global health framing of mosquito nets as 'a solution', as an intervention that stops mosquitoes transmitting malaria. This resonates with work in environmental history that understands human relations with harmful environmental forces as "inevitable ecologies" (Nash, 2007), or as "ecologies of complexity" that make the eradication of disease "unlikely, if not impossible" (Tilley, 2004: 21). In this sense my focus is here close to Nigel Clark (2011), who suggests that in conventional understandings environmental justice is something to be done to the environment. Clark instead proposes an extended understanding of environmental justice, one that asks what would happen if we understand environments as active, as making or indeed taking their own justice (Clark, 2011: 107–136)?

[5] Despite a massive increase in Grameen style micro-credit initiatives over the last decade, the micro-finance industry "has yet to reach 5% of the customers among the poor world" (Moyo, 2009, p.132). However, micro-credit initiatives are by no means a silver bullet for poverty alleviation, economic stimulation and equitable development. Micro-credit initiatives have for instance been criticised for being socially repressive through overly aggressive repayment policies (Montgomery, 1996; Rahman, 1999), for not reaching the poorest, most vulnerable groups (Amin et al., 2003; Datta, 2004), and for having lost sight of broader developmental goals (such as promoting livelihoods, empowering women and changing institutions) (Fisher and Sriram, 2002)

[6] And thus do not need to be re-treated regularly with insecticides as Insecticide-treated nets require. Insecticide-treated nets are recommended to be re-treated every 6 months to a year.

[7] Malaria also occurs in Vietnam and Thailand, and thus is needed locally. However, the overwhelming majority of malaria cases and deaths happen in sub-Saharan Africa, which is thus the main market for the nets manufactured in Vietnam and Thailand.

Clark's insight chimes with the questions entomologists are concerned with. For them the debate about mosquito nets does not stop with the political economy of production and distribution, but has another, more subtle future perspective too – as a Ghanaian professor of entomology put it:

> "If one manipulates something in an ecosystem, something else will change too. This is competition, the mosquitoes need their blood meal, they will react. So, for example, with the flooding of bed nets into Africa, one needs to ask, what does the mosquito do? One needs to look at the mosquitoes' perspective on bed nets. They don't get their blood meal, if we are lucky and there are enough cows or other animals around, they might start biting those. If we are unlucky, they might just start biting earlier, at around 6pm for example, then the bed nets don't help that much anymore. We need to pay attention to these subtle things."
>
> [Interview Professor A., 2008]

The female *Anopheles* mosquito needs blood to nurture her eggs, human blood is a means for the mosquito to secure offspring and the future of its species. So, not only for humans the stakes are high. Insecticide-treated nets kill and repel mosquitoes by establishing a physical and chemical barrier between mosquitoes and blood. Thus, as my interview partner points out mosquitoes do not have much choice: if too many nets are around they have to react. There are two main adaptations; *behavioural* adaptations and *bodily* insecticide tolerance in mosquitoes. Behavioural adaptations refer to changes in blood-seeking behaviour that have been observed scientifically, such as changes in biting times or in the choice of host. What I call (for want of a better term) bodily tolerance are changes in the genetic composition of mosquito bodies.

Insecticides are important tools in malaria control, and they are used in two major control interventions – insecticide-treated mosquito nets and indoor residual spraying.[8] Similar (and to a certain extent the same) insecticides have furthermore been used in agricultural pest control. Thus exposure to insecticides has historically been high, and has led to widespread development of resistance. I will discuss behavioural resistance later, and now briefly introduce the main adaptations that I call *bodily*. The currently known bodily resistance mechanisms are three: (a) target-site resistance, which are mutations in the insects' nervous system (to be precise in the voltage-gated sodium channel) that are targeted by the insecticides; (b) metabolic resistance, which label elevated activities of enzymes that detoxify the insecticide before it reaches the nervous system (its target site); and (c) cuticular resistance, which are changes in the cuticles that result in reduced uptake of insecticides in the mosquitoes bodies (in mosquitoes uptake is primarily through the appendages) (Ranson et al., 2011, p. 91–93).

For insecticide-treated nets compounds from one class of pesticides (pyrethroids) are recommended (Enayati and Hemingway, 2010). Pyrethroid resistance has already been reported from West Africa before the broad introduction of insecticide-treated nets – for instance from several parts of Côte d'Ivoire since 1993 (Tia et al., 2006) and Benin (Akogbéto and Yakoubou, 1999). Today, pyrethroid resistance is not only widespread in West Africa, but has been reported in 64 countries with on-going malaria transmission (WHO, 2012). It is presumed that resistance mainly originated in West Africa because of the long-standing and widespread insecticide spraying – against malaria, but even more so for agricultural use on cotton and cocoa plantations. And it is at this point that yet another complication enters the picture. The repertoire of insecticides that are both effective and toxicologically safe is limited, which has led to the rise of another type of resistance – cross-resistance. While for insecticide-treated nets only pyrethroids are in use, for spraying 12 insecticides from four classes are recommended (WHO, 2006, p. 6). Out of these dichlorodiphenyltricholoethane (DDT), malathion and Deltamethrin (a pyrethroid) are the most cost-effective (in this order, Sadasivaiah et al., 2007, p. 254). And this is where the problem comes in. The four classes of insecticides target in total only two neurological sites (Brooke, 2008). DDT and pyrethroids share the same mode of action on the nervous system of mosquitoes; they target the neuronal voltage-gated sodium ion channels (Santolamazza et al., 2008). Unsurprisingly, the genetic mutations that make mosquitoes tolerant of the insecticides are similar too. Resistance to DDT often also conveys resistance to pyrethroids and vice versa, they are cross-resistant.

It is at this point that agricultural and health use of insecticides converge. Take Ghana for instance: cotton is grown in Ghana (mainly in the North), but cocoa production is of greater national importance. In the 1960s Ghana was the largest cocoa producer worldwide. While today Ghana's neighbour Côte d'Ivoire has taken over this title, cocoa remains the most important crop in the country's agricultural sector, particular in the forest areas in middle Ghana. DDT and pyrethroids were both popular insecticides used in the 1960–1970s on those plantations (Pinto et al., 2007; Entomologist A, Interview 2008). Pest control through insecticide spraying with DDT has been officially banned in Ghana since 1985 (Environmental Protection Agency Ghana, 2006). As a result of the DDT ban, pyrethroids – including deltamethrin, the insecticide used for insecticide-treated nets – gained importance in the Ghanaian cocoa pest control in the 1980s, and remains in use until today (Batemann, 2008). In addition, there has been a significant increase of antimalarial indoor spraying in Ghana since 2007, which will effect the development of resistance further. Thus, insects not only come into contact with pyrethroids through insecticide-treated nets, or antimalarial spraying, but through a combination of global health and agricultural insecticide use, which increases selection pressure. The regional history of agricultural and vector control practices intersects, and is inscribed as the "biology of history" in the mosquitoes' genome (Landecker, 2015).

It is assumed that the different mutations primarily confer high DDT and low pyrethroid resistance (Enayati and Hemingway, 2010, p.579). But these mutations are present in a big part of the mosquito populations. For instance, in one study with *Anopheles gambiae* (the main malaria vector in sub-Saharan Africa) the mutated genotype was detected in more than 98% of the specimens (Santolamazza et al., 2008, p.8). The so-called 'operational effects' on insecticide-treated nets are still unclear. In Benin the effectiveness of insecticide-treated nets was found to be compromised by 70% in an area with pyrethroid-resistant mosquitoes (N'Guessan et al., 2007). In a later study in Benin it was found that "sleeping under an ITN [insecticide-treated net] in the location with resistant mosquitoes was no more protective than sleeping under an untreated net" (Asidi et al., 2012). However, other studies by Darriet et al. (2000) and Asidi et al., 2004, 2005) showed that insecticide-treated nets retained their effectiveness in killing mosquitoes and minimising blood-feeding despite frequent detection of resistance in *A. gambiae* mosquitoes. Generally however, such results are of limited predictability, because mosquito evolution can happen quickly: "a high rate of generation turnover and associated genetic recombination, means that insecticide resistance can arise rapidly in vector populations under intense insecticide selection pressure" (Brooke, 2008, p. 225). And currently, resistance spreads at an "exceptionally rapid rate" (Ranson et al., 2011, p. 91). It is agreed in the malaria community that resistance and cross-resistance are likely to have a significant operational effect on insecticide-treated nets (WHO, 2012).

[8] Indoor-residual spraying refers to the spraying of indoor walls in human-inhabited buildings. Aerial spraying was discarded as a technique after the detrimental effects of DDT for the wider environment became known in the1960s (Carson, 1962).

To make matters worse, mosquitoes cannot only develop bodily tolerance to insecticidal toxins, but also evade insecticide-treated nets in other ways. Change in behavioural patterns have been observed, where biting habits of mosquitoes have shifted to earlier hours circumventing insecticide-treated nets. As a precursor to this section it is important to point out that behavioural adaptations are called 'behavioural' because those are changes that can be read from mosquitoes' behaviour, their actions. Such changes will of course not be *learned* behaviour from *one* mosquito. Changes are mainly subpopulation-level changes, and are detectable for scientists through different prevalence rates of subpopulations. In other words, subpopulations of *Anopheles* mosquitoes with slightly different biting habits, i.e. the ones that bite earlier, have a higher survival advantage and shift their ecological niche. This means more mosquitoes with earlier biting cycles will survive, and develop dominant traits, which ultimately leads to population changes. This makes it sound a slow process; however, with a mosquito life expectancy of 10–20 days, generation turnover is fast.

One of my informants has started to observe such behavioural adaptations in *Anopheles*: Dr. W. observed that the biting cycle has changed slightly in the north of Ghana. While in the south of the country *Anopheles* bites peak at 10 pm and between 12 pm and 1 am, in the North there seems to be a third peak developing, between 5 and 6 am. And Dr. W. reports that those were the mosquitoes with the highest parasite loads. To him this is "very scary" as it means that the effectiveness of nets is already compromised, because many people (particular in rural areas) will be out of the net's protective space by 5–6 am. And the area where Dr. W. and his team have done this work is the region, where also the first insecticide-treated nets trials in Ghana happened (Binka et al., 1998). So Dr. W. speculates that those mosquitoes that started biting between 5 and 6 am might have already adapted to insecticide-treated nets. In order to prove this hypothesis the team from the Noguchi Research Institute has been doing some work in the neighbouring district, where fewer insecticide-treated nets can be found. They then hope to compare the data sets and have more conclusive evidence about the changes in biting cycles and insecticide-treated nets.

One study from Tanzania gives us very interesting insights into changes that are occurring. The study was conducted in an area that before the introduction of insecticide-treated nets already had a very high coverage of untreated nets, which means the effects of both untreated and then insecticide-treated nets could be studied. The study showed dramatically increased outdoor feeding of mosquitoes and changes in biting times can be clearly linked to the use of insecticide-treated nets. After the introduction of untreated nets, indoor feeding of mosquitoes decreased slightly in the area, but not significantly. However, this changed drastically after the introduction of insecticide-treated nets: "it was strikingly clear that after the introduction of ITNs [insecticide-treated nets], the proportion of human contact occurring indoors was reduced as contact occurring outdoors in the early evening proportionally increased (Russell et al., 2011, p.4).

Thus, the development of resistance is significantly accelerated by the use of insecticides on the nets. Mosquito nets without insecticides have existed for centuries, and offered sleeping humans good protection. So, why was insecticide treatment introduced in the first place? Well-maintained untreated nets (read: nets without holes) protect the person as long as they are under the net, and have been found to reduce malaria prevalence significantly (by 51% in comparison to no net use, Clarke et al., 2001). In addition to this protection, insecticide-treated nets kill mosquitoes that come into contact with the nets, and repel those that come close. The repellence is the major advantage of using insecticides, they basically extend the protection zone of the net. The number of mosquitoes found resting in the house was found to be significantly higher in rooms where an untreated net was hung in comparison to rooms where a treated net hung (Snow et al., 1987). Thus, insecticide-treated nets also reduce mosquito bites outside of the net inside the room, which is – one presumes – a significant advantage over untreated nets. However, oddly enough when the WHO research unit TDR commissioned a large-scale four-country study into the effect of insecticide-treated nets on overall child mortality in the 1990s, no systematic comparison with untreated nets was done. The effect of insecticide-treated nets on child mortality was only compared to non-usage[9] (Binka et al., 1996; D'Alessandro et al., 1995; Nevill et al., 1996). As I discussed above, roughly 15 years after the introduction of insecticide-treated nets, the effects of insecticide use on mosquito populations can be observed. Insecticide-treated nets have brought down malaria transmission significantly in areas with high coverage. In the area in Tanzania that I discussed above, bed net use has brought down the transmission intensity of malaria by 94% (Russell et al., 2011). At the same time, significant changes in biting times and indoor-outdoor patterns have been observed, and they reduce the effectiveness of nets and spraying drastically:

> "High usage of ITNs [insecticide-treated nets] can dramatically alter African vector populations so that intense, predominantly indoor transmission is replaced by greatly lowered residual transmission, a greater proportion of which occurs outdoors. Regardless of the underlying mechanism, the residual, self-sustaining transmission will respond poorly to further insecticidal measures within houses. Additional vector control tools which target outdoor biting mosquitoes at the adult or immature stages are required to complement ITNs [insecticide-treated nets] and IRS [indoor-residual spraying]."
> [Russell et al., 2011, p. 1.]

In other words, increases in outdoor biting and decreases in nocturnal biting mean that both nets and indoor-residual spraying of insecticides loose their effectiveness, and additional measures are required. Importantly though, these changes have to be interpreted as a result of the *success* of insecticide-treated nets. Because the nets are such powerful tools to restrict blood feeding of mosquitoes, they are changing population patterns dramatically (ibid.). Thus, as we can see, and as the history of (failed) eradication attempts shows too (Packard, 2007), mosquito populations are quick to adapt, bounce back or move back in once interventions stop (Molineaux and Gramiccia, 1980). The most stable characteristic of mosquito control might well be its changeability. Environmental management of malaria has more than humans as active actants – mosquitoes are worthy sparring partners. It is a game of intervention and response – the mosquitoes' mutations continue to challenge human interventions. In this sense managing mosquitoes is close to Krause's (2015) understanding of "heterogenous engineering", as he puts it (paraphrasing Lucy Suchman): "the configurations that make them emerge, but rather about the practices of configur*ing*, and continually re-configuring, the attempts to stabilise a particular trajectory" (Krause, 2015).

This section introduced mutating mosquitoes and insecticide resistance as a second disentanglement from malaria policies. However, mutating mosquitoes do not escape policies in the sense market politics have escaped global health logics. Insecticide resistance does actually form part of malaria control policies, in this sense it is visible. In particular since 2012 when WHO published a 'Global Plan for Insecticide Resistance Management in Malaria Vectors' (WHO, 2012). Nevertheless, mutations escape the grip of policies and environmental management. It escapes in the way

[9] The control groups of the study continued to live the way they lived before. The prevailing practices are not explained in detail in the study protocol, but from the short comments made in the papers can be assumed to be mainly non-usage of nets.

Professor A. has explained, "mosquitoes will adapt to whatever the human will do". And importantly, this reaction will always include surprise (Gross, 2010). No matter how much research efforts are strengthened, at best scientists and environmental managers can make an informed guess about what could happen, but they cannot know. The agency at work here is decidedly non-human. The resistance management that the recent WHO Global Plan for Insecticide Management advocates is mainly aimed at keeping resistance at low levels in the mosquito population, slow down its spread and so maintain the effectiveness of vector control tools until new technologies have been developed.[10] In other words, the mutant characteristics of the initial control activities are not addressed sustainably; although insecticide resistance may change policies and malaria control practices, the response is just going to only buy humans time.

4. Conclusions

So, what to make of the economic and ecological disentanglements of mosquito nets? Firstly, we have seen that by construing mosquito net production and distribution as a merely technical issue, space is granted to an alliance of industry, international NGOs and regulation authorities to build an international market for nets, which disentangles and marginalises local net sewing economies. Understanding mosquito nets as 'free' humanitarian goods, as tools of global health that 'save lives' masks the politics of the market that are going on with and around insecticide-treated nets. As I show, international companies coming from Europe and Japan are the major producers of mosquito nets, while African enterprises have almost no involvement in net manufacturing. This factory production of mosquito nets also put long established, decentralised, local and small-scale net-sewing and -selling economies out of business. Considering that most people on this vast 1 billion-inhabitant continent would ideally own a mosquito net, net production could for instance have been connected to one of the many economic development initiatives on the continent (many of which are supported by the same Western donors who subsidize mosquito nets). Instead, mosquito net donations end up benefiting companies from developed countries, conveying only one of potentially many benefits to the African end-user – protection from mosquito bites.

Secondly, I show that insecticide-treated nets are challenged by – what I termed – mosquito logics. Agricultural and global health use of insecticides diminishes prospects of species survival and become a threat for mosquitoes. Through developing tolerance to insecticides and net-evading blood-seeking behaviour mosquitoes respond to insecticide-treated nets, and in the long run threaten the success of the intervention. This points to an underlying dynamic in disease control, and enables us to question current malaria control strategies: is the advantage we get from using insecticides on nets really worth its cost? Might it backfire through increased selection pressure and the evolution of resistant mosquitoes? The outmoded hand-sown and insecticide-free net that Daniel's mum produced serves to remind us that modest strategies of malaria control might offer themselves up as a *slow* tool of malaria management, and that slowing things down (rather than accelerating) might lead us to another cosmopolitics in human–nonhuman encounters (Bingham, 2008; Stengers, 2010). What if managing mosquitoes is not about how to best eliminate them, but about asking how we might find ways to tolerate coexisting with each other? Daniel's mum's mosquito net nudges us to rethink malaria management strategies – away from elimination, towards a more humble and localised strategy of coexistence (Beisel, 2010b; Tironi and Farías, 2015). This then suggests a different spatio-temporal politics to the grand narrative of eradication. A politics that, instead of going to war with mosquitoes and parasites, works towards acknowledging and taking seriously the agency and vitality of mosquitoes in particular socio-economic and ecological contexts. A politics that carefully, slowly and step-by-step reworks the complex knots of mosquito–human–para site entanglements – pulling a few strings apart and reconnecting others. As insecticide resistance shows, such a slower and 'smaller' spatio-temporal politics is not necessarily motivated by altruism or love for mosquitoes, but might be a rather selfish strategy for humans; in the sense that – in the long run – it might offer better and more sustainable survival strategies.

This paper has focused on the political economy, social and ecological life of insecticide-treated nets, in order to better understand what makes mosquito nets valuable and for whom. I have argued that while global health logics are firmly front stage in the management of mosquitoes with insecticide-treated nets, these logics entail overflows, or rather have created disentanglements that challenge the valuation of mosquito nets as purely humanitarian goods. 'Forgotten' market logics, as well as mosquito logics question how mosquitoes are currently managed through the use of insecticide treated nets. A global health logic that focuses on numbers of distributed nets and lives saved obscures the net's broader socio-economic effects and ecological consequences. I have argued that paying systematic attention to what becomes disentangled in insecticide-treated nets as global health commodities, gives texture to the goods and bads of good intentions; the unintended effects of the moral and medical values of humanitarian goods, which are designed to find solutions for problems global health assumes states cannot solve (Redfield, 2012). This, however, is not to be read as a critique of mosquito nets that devalues them as a tool of malaria management (Latour, 2004). On the contrary, I argued that mosquito nets could do *even more* than they do today: they have the capacity to not only keep people from contracting malaria and managing mosquitoes, but could contribute to economic empowerment in sub-Saharan Africa and help articulate an ecological modesty of humans towards mosquitoes.

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[10] This the Global Plan hopes is to be achieved by rotating insecticides, combining interventions, mosaic spraying (using different insecticides in bordering areas), and mixing different insecticide classes in one insecticide (WHO, 2012: 44).

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