Executive summary
Malaria in South Africa is seasonal and primarily occurs in the Limpopo, Mpumalanga and KwaZulu-Natal provinces. The control of malaria vector mosquito species is based on indoor spraying of residual insecticides (IRS) and limited larval source management. Malaria incidence in 2017 was unusually high and was characterised by a substantial increase in sporadic, locally acquired cases. Unusually high rainfall and delayed IRS activities in some municipalities may have facilitated this higher rate of transmission. Vector surveillance in collaboration with the National Institute for Communicable Diseases (NICD) during 2017 revealed the presence of three malaria vector species - *Anopheles arabiensis*, *An. merus* and *An. vaneedeni* – which have previously been shown to contribute to ongoing residual malaria transmission in South Africa. Several closely related non-vector *Anopheles* species were also collected. Most of the specimens analysed were collected from Mpumalanga (46.8%) and KwaZulu-Natal (32.2%) provinces with smaller proportions collected from Limpopo Province (10.2%) and the Kruger National Park (10.8%). The surveillance information by province and municipality shows that IRS-based vector control needs to be maintained at a high rate of coverage, that IRS activities should ideally be completed before the onset of each malaria season and that winter larviciding based on the WHO’s ‘few, fixed and findable’ approach may enhance the effect of IRS in high incidence areas.

Introduction
South Africa’s malaria affected areas include the low altitude border regions of Limpopo, Mpumalanga and KwaZulu-Natal Provinces. These regions typically experience active malaria transmission, especially during the peak malaria season that spans the summer months of November to April. However, 2017 proved to be an extraordinary year with incidence peaking in May and October. In general, malaria incidence increased approximately three-fold (+/- 31000 cases) in 2017 over that
recorded in 2016 (9 478 cases), with Limpopo and Mpumalanga provinces most affected, especially the Vhembe, Mopani (Limpopo) and Ehlanzeni (Mpumalanga) districts.¹

Each of South Africa’s malaria endemic provinces have developed well-coordinated malaria control operations including routine vector control which is primarily based on the application of indoor residual insecticide spraying (IRS) and, to a lesser extent, larval source management.² Although IRS has proven efficacy spanning many decades, residual malaria transmission continues and is likely caused by outdoor feeding and resting Anopheles vector mosquitoes that are unaffected by indoor applications of insecticide.³⁴ In addition, populations of the major malaria vector species, Anopheles funestus and An. arabiensis, have developed resistance to insecticides, especially in northern KwaZulu-Natal.⁵ However, the pyrethroid resistance phenotype in An. arabiensis in this region is currently of low intensity and is unlikely to be operationally significant at this stage, unlike the pyrethroid-carbamate resistance profile in An. funestus which is of high intensity, is highly significant epidemiologically and was at least partly causative of the malaria epidemic experienced in South Africa during the period 1996 to 2000.⁶

Residual malaria transmission, substantially increased incidence and burgeoning insecticide resistance in malaria vector populations within South Africa’s borders necessitate ongoing and enhanced vector surveillance. This is especially pertinent in terms of South Africa’s malaria elimination agenda.⁷ Currently, surveillance is routinely conducted by the entomology teams of Limpopo, Mpumalanga and KwaZulu-Natal provinces with support from partner institutions including the National Institute for Communicable Diseases (NICD), the Wits Research Institute for Malaria (WRIM), University of the Witwatersrand, the Institute for Sustainable Malaria Control, University of Pretoria and the South Africa Medical Research Council. This report summarises malaria vector surveillance in South Africa in 2017 based on specimens referred to the Vector Control Reference Laboratory (VCRL) of the Centre for Emerging Zoonotic and Parasitic Diseases (CEZPD), NICD.

Methods
During the period January to December 2017, Anopheles mosquitoes were collected by the provincial entomology teams and partner institution personnel. Adult specimens were obtained by rearing larvae from routine larval collections and adults were also periodically collected using trapping techniques including exit window traps, clay pots, modified buckets, human landing catches (HLC) and CO₂ baited net traps. One or more of these collection techniques were deployed at sentinel sites in Limpopo, Mpumalanga and KwaZulu-Natal provinces (Figure 1). Adult mosquitoes were preserved on silica and sent to the NICD for species identification. Identification of all mosquito specimens was based on the use of morphological keys and PCR. All results were subject to rigorous quality assurance according to the ISO/IEC 17025:2005 accreditation system before being entered into the database.

Results & Discussion
A total of 1 898 Anopheles mosquitoes was collected from sentinel sites during the period under review (Figure 1). Of these, 889 (46.8%) were collected from Mpumalanga, 611 (32.2%) from KwaZulu-Natal, 193 (10.2%) from Limpopo and 205 (10.8%) from the Kruger National Park. The vast majority were members of the An. gambiae species complex (1 551; 81.7%) and the remaining 18.3% (347) were members of the An. funestus species group. Subsequent PCR analysis revealed that the An. gambiae complex included An. arabiensis, An. merus and An. quadriannulatus. The An. funestus group
were identified as *An. rivulorum*, *An. vaneedeni*, *An. parensis*, *An. rivulorum*-like and *An. leesoni*. A summary of the species collected by relative proportion by province and species group is given in Figure 2.

![Map showing malaria vector surveillance sentinel sites disaggregated by *Anopheles* species group/complex, Limpopo, Mpumalanga and KwaZulu-Natal provinces, South Africa, January to December 2017.](image)

**Figure 1:** Malaria vector surveillance sentinel sites disaggregated by *Anopheles* species group/complex, Limpopo, Mpumalanga and KwaZulu-Natal provinces, South Africa, January to December 2017.

*Anopheles arabiensis* was predominant in Mpumalanga and KwaZulu-Natal provinces (Figure 2 A,C) and was collected in smaller numbers in Limpopo Province and the Kruger National Park (KNP). It is a major malaria vector in South Africa with variable feeding and resting behaviours. Outdoor feeding and resting components of *An. arabiensis* populations are at least partially responsible for ongoing residual malaria transmission.

*Anopheles merus* was collected in the greatest relative proportion in Mpumalanga followed by KwaZulu-Natal provinces with only one specimen collected in the KNP (Figure 2 A,C,G). This species has previously been detected in Limpopo province. *Anopheles merus* is a minor or secondary malaria vector in South Africa and has also been implicated in transmission in southern Mozambique. Interestingly, this species is traditionally described as a salt-water coastal breeder but the larval collections from which most of these specimens accrued were found in fresh-water breeding sites. Recent data from Mpumalanga Province suggest that this species is increasing its inland range and abundance by adapting to breeding in fresh-water habitats.
Anopheles quadriannulatus is a non-vector member of the An. gambiae complex that is common in the southern African region including South Africa. This species predominated in Limpopo Province and the KNP, was detected in smaller numbers in Mpumalanga Province and in low numbers in KwaZulu-Natal Province (Figure 2A,C,E,G).

Anopheles vaneedeni was collected in all three endemic provinces in varying abundance. This species tends to rest outdoors and will readily feed on humans. It has recently been implicated as a secondary malaria vector in Mpumalanga and KwaZulu-Natal provinces³ (Figure 2 B,D,F).

No An. funestus sensu stricto were collected during the review period. In the absence of vector control, this species is the predominant malaria vector in the southern African region where it is especially prevalent in neighbouring Mozambique and Zimbabwe. Although the eastern Lowveld regions of South Africa form part of the natural range of this species, its absence is likely attributable to intensive IRS programmes in KwaZulu-Natal, Mpumalanga and Limpopo provinces. However, the possibility of transmission by this species in the border regions of Limpopo cannot be ruled out owing to a paucity of data from that region. Other members of the An. funestus group were detected in Limpopo, Mpumalanga, and KwaZulu-Natal provinces and in the KNP in comparatively low numbers (Figure 2 B,D,F,H). Anopheles leesonii, An. rivulorum-like and An. parensis are generally considered to be non-vector species while An. rivulorum has been implicated as a minor malaria vector in East Africa. The possibility of one or more of these species playing a role in residual malaria transmission in South Africa cannot be ruled out.
Figure 2: Relative proportions of member species of the *Anopheles gambiae* complex and *An. funestus* group by province/locality, South Africa. These proportions are based on *Anopheles* specimens collected during the period January to December 2017.
The sporadic nature of entomological surveillance activities in 2017 coupled with the sporadic occurrence of local cases negates the possibility of establishing direct correlations between the *Anopheles* samples described here and the unusually high incidence of locally acquired malaria in South Africa’s endemic areas in 2017. Nevertheless, one or more confirmed or suspected vector species were detected in all of the high-incidence / high-risk municipalities of Mpumalanga and Limpopo provinces, and in the lower risk municipalities of Jozini in northern KwaZulu-Natal Province and Waterberg in western Limpopo Province (Table 1).

**Table 1:** Occurrence of confirmed or suspected *Anopheles* malaria vector species by province and municipality, South Africa, January to December 2017.

<table>
<thead>
<tr>
<th>Province</th>
<th>Municipality/District</th>
<th>Vector species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpumalanga</td>
<td>Bushbuckridge</td>
<td><em>An. arabiensis, An. merus, An. vaneedeni</em></td>
</tr>
<tr>
<td></td>
<td>Mbombela &amp; Nkomazi</td>
<td><em>An. arabiensis, An. merus</em></td>
</tr>
<tr>
<td>Limpopo</td>
<td>Vhembe</td>
<td><em>An. arabiensis, An. rivulorum</em></td>
</tr>
<tr>
<td></td>
<td>Mopani</td>
<td><em>An. rivulorum</em></td>
</tr>
<tr>
<td></td>
<td>Waterberg</td>
<td><em>An. arabiensis, An. vaneedeni</em></td>
</tr>
<tr>
<td>KwaZulu-Natal</td>
<td>Jozini</td>
<td><em>An. arabiensis, An. merus, An. rivulorum, An. vaneedeni</em></td>
</tr>
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</table>

**Conclusion & recommendations**

Several anophelines, including malaria vector species, occur in the north-eastern Lowveld regions of South Africa. Despite coordinated provincial IRS programmes that generally achieve high spray coverage rates (80% or more of targeted structures in endemic areas), populations of these species persist and at least three of them - *An. arabiensis, An. merus* and *An. vaneedeni* – have previously been implicated in ongoing residual transmission (tentative in the case of *An. merus*). The reasons for this are multiple and certainly include outdoor-biting and outdoor-resting components of these species. In addition, unusually high rainfall and delayed IRS activities in some municipalities may have facilitated a higher rate of transmission, notwithstanding a range of other sociological variables that are beyond the scope of this report.

Based on this information it is recommended that:

- IRS based vector control be maintained at a high rate of coverage in endemic districts
- IRS activities should ideally be completed before the onset of each malaria season
- Winter larviciding based on the WHO’s ‘few, fixed and findable’ approach be implemented to enhance the effect of IRS in high incidence areas

**Acknowledgements**

Entomology team members of the provincial Malaria Control Programmes of KwaZulu-Natal and Mpumalanga are thanked for the referral of surveillance specimens to the VCRL. Dr Patrick Moonasar, Dr Eunice Misiani, Prof Rajendra Maharaj, Mr Aaron Mabuza, Mr Eric Raswiswi, Mr Philip Kruger, Prof
Immo Kleinschmidt and all members of the South African Malaria Elimination Committee (SAMEC) are especially thanked for their support for vector surveillance. The Kruger National Park management and staff are thanked for their support during collections in the park. These activities were sponsored by the Mpumalanga and KwaZulu-Natal Malaria Control Programmes, the National Institute for Communicable Diseases, CDC/GDD (Global Diseases Detection programme) grant (U19GH000622-01 MAL01), the South African MRC Collaborating Centre for Multidisciplinary Research on Malaria, the International Atomic Energy Agency, the Industrial Development Corporation and the South African Nuclear Energy Corporation (NECSA) through its Nuclear Technologies in Medicine Biosciences Initiative (NTeMBI) – a national platform funded by the Department of Science and Technology. MC and LK are supported by a NRF/DST Research Chair Initiative grant.

References