MALARIA VECTOR SURVEILLANCE REPORT, SOUTH AFRICA, JANUARY – DECEMBER 2018

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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 2018 was comparatively high with 18 638 confirmed malaria cases and 120 confirmed deaths. Vector surveillance in collaboration with the National Institute for Communicable Diseases (NICD) during 2018 revealed the presence of three malaria vector species - *Anopheles arabiensis* (n=775, 36%), *An. merus* (n=219, 10%) and *An. vaneedeni* (n=129, 6%) – which have previously been shown to contribute to ongoing residual malaria transmission in South Africa. In addition to these, *An. parensis* (n=231, 11%) has recently been incriminated as a minor vector in South Africa. Several closely related non-vector *Anopheles* species were also collected. Most of the specimens analysed were collected from KwaZulu-Natal (61%, n= 1 324) followed by Limpopo (23%, n=491) and Mpumalanga (16%, n = 366) provinces. The surveillance information by province and municipality shows that IRS based vector control needs to be maintained at a high rate of coverage and that spraying should ideally be completed before the onset of each malaria season. Given that all sporozoite positive (and therefore malaria infective) adult *Anopheles* females recently collected were found resting outdoors, and given that there are no large-scale vector control tools targeting

outdoor-resting mosquitoes, larviciding, including the treatment of winter breeding sites, should be used as a complimentary method to 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. Malaria incidence in 2018 (18 638 cases) decreased by approximately half of that recorded in 2017 (+/- 31 000 cases) but was still substantially higher than that of 2016 (9 478 cases). Limpopo and Mpumalanga provinces were 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.[3,4] In addition, populations of the major malaria vector species, *Anopheles funestus* and *An. arabiensis*, have developed resistance to insecticides, especially in northern KwaZulu-Natal.[2,5] The pyrethroid resistance phenotype in *An. arabiensis* in this region is however of low intensity currently and is not considered 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, comparatively high 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, the South African Medical Research Council and the Clinton Health Access Initiative. This report summarises malaria vector surveillance in South Africa in 2018 based on specimens referred to the Vector Control Reference Laboratory (VCRL) of the Centre for Emerging Zoonotic and Parasitic Diseases (CEZPD), NICD.

Methods

Anopheles mosquitoes were collected from sentinel sites in KwaZulu-Natal, Limpopo and Mpumalanga provinces (Figure 1). These specimens were either collected by VCRL personnel or were referred to the VCRL by partner institutions and provincial malaria control programme entomology teams during the period January to December 2018.

Adult *Anopheles* mosquitoes were collected by baited net traps (goat and cow baited), silver bullet traps (UV LED, white light and no light), CO_2 traps, resting in tyres, outdoor placed clay pots and modified buckets, and by human landing catches. Other specimens were collected as larvae and were reared to adults for subsequent analysis. One or more of these collection techniques were deployed at each sentinel site (Figure 1). Adult specimens were preserved on silica gel in 1.5ml tubes and were identified as far as possible using external morphological characters by VCRL, partner institution and/or provincial malaria control programme personnel. Specimens identified as members of the *An. gambiae* complex or *An. funestus* group were subsequently identified to species using standard polymerase chain reaction (PCR) assays. Quality assurance based on the ISO 17025 standard was used to ensure the quality of results.

Results

A total of 2 181 *Anopheles* mosquitoes was collected from sentinel sites in the Umkhanyakude region in KwaZulu-Natal Province, the Vhembe region of Limpopo Province and the Ehlanzeni region of Mpumalanga Province (Figure 1).

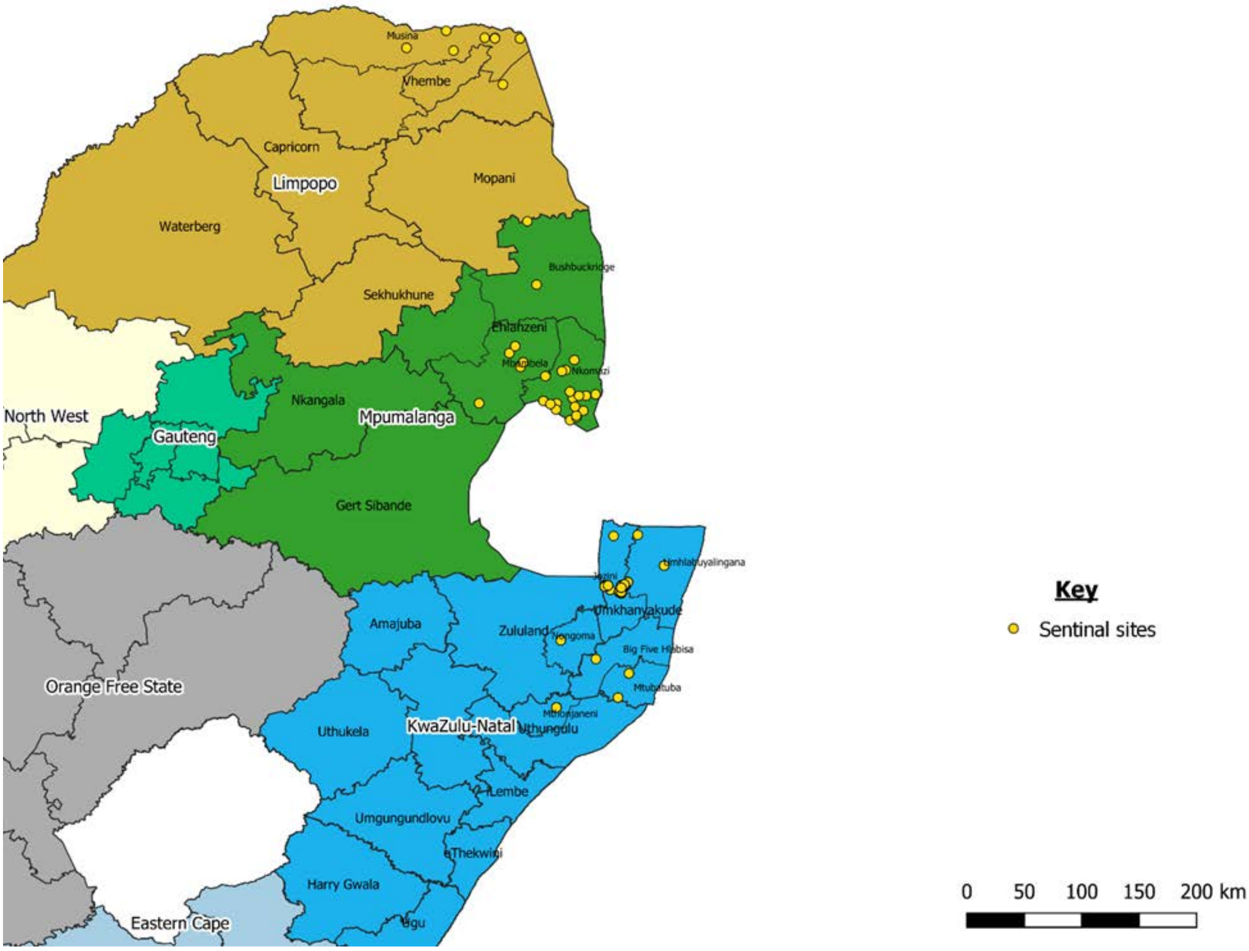

Figure 1: Sentinel *Anopheles* collection sites in KwaZulu-Natal, Limpopo and Mpumalanga provinces, South Africa, 2018.

Most of the specimens were collected from KwaZulu-Natal (61%, n=1 324) followed by Limpopo (23%, n=491) and Mpumalanga (16%, n=366) provinces (Table 1, Figure 2). These were subsequently identified as members of the *An. gambiae* complex (60%, n=1 312), *An. funestus* group (30%, n=658) or other *Anopheles* species (10%, n=211). *Anopheles arabiensis* predominated the collections (36%, n=775) although substantial numbers of *An. merus*, *An. quadriannulatus*, *An. parensis*, *An. vaneedeni* and *An. rivulorum* were also obtained (Table 1, Figure 2).

Table 1: Numbers of *Anopheles* specimens collected by species and province, South Africa, 2018.

***Anopheles* species complex, group or other**	***Anopheles* species**	**KwaZulu-Natal**	**Limpopo**	**Mpumalanga**	**Total**
***An. gambiae* complex**	*An. arabiensis*	614	49	112	775
	An. merus	66	9	144	219
	An. quadriannulatus	63	150	105	318
***An. funestus* group**	*An. leesoni*	27	19	0	46
	An. parensis	229	2	0	231
	An. rivulorum	100	133	1	234
	An. rivulorum-like	0	18	0	18
	An. vaneedeni	81	46	2	129
Other *Anopheles* species	*An. coustani*	11	3	0	14
	An. demeilloni	0	1	0	1
	An. listeri	0	15	0	15
	An. marshallii	96	0	0	96
	An. pharoensis	5	0	0	5
	An. pretoriensis	28	15	0	43
	An. rhodesiensis	0	1	0	1
	An. rufipes	1	16	0	17
	An. squamosus	3	2	2	7
	An. tenebrosus	0	12	0	12
Total		1324	491	366	2181

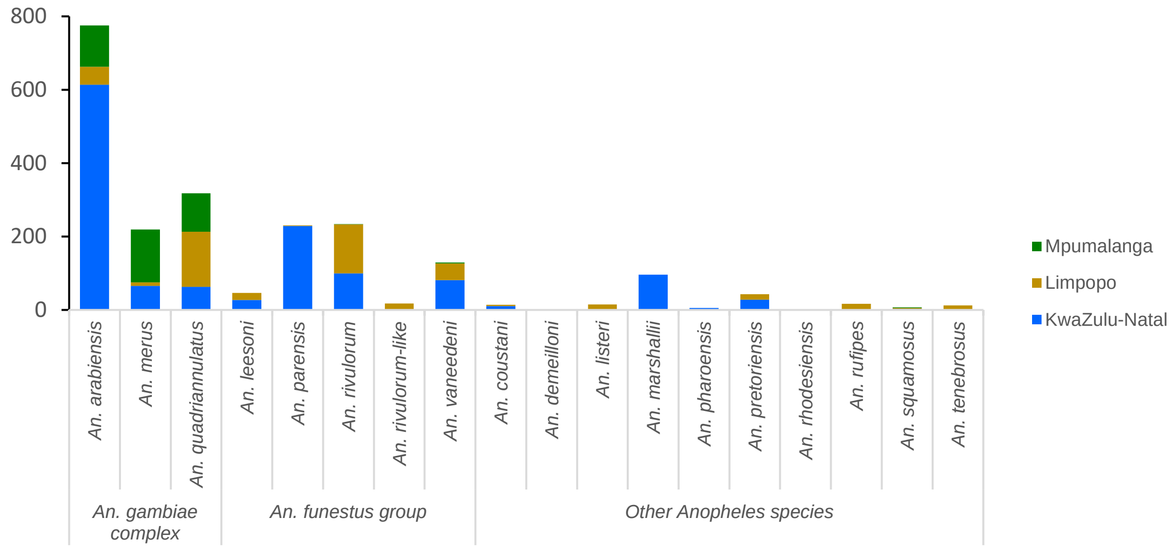

Figure 2: Proportional distribution (in absolute numbers) of *Anopheles* specimens collected by species and province, South Africa, 2018.

The malaria vectors *An. arabiensis* and *An. merus* (members of the *An. gambiae* species complex) were collected from sentinel sites in all three endemic provinces (Table 1, Figure 3). In KwaZulu-Natal Province, populations of these species were found in Jozini, Umhlabuyalingana and Mtubatuba municipalities of the Umkhanyakude District. In Limpopo Province, populations of these species were found in Musina and Collins Chabane of the Vhembe District. In Mpumalanga Province's Ehlanzeni District, these species were found in Nkomazi, Bushbuckridge and Mbombela.

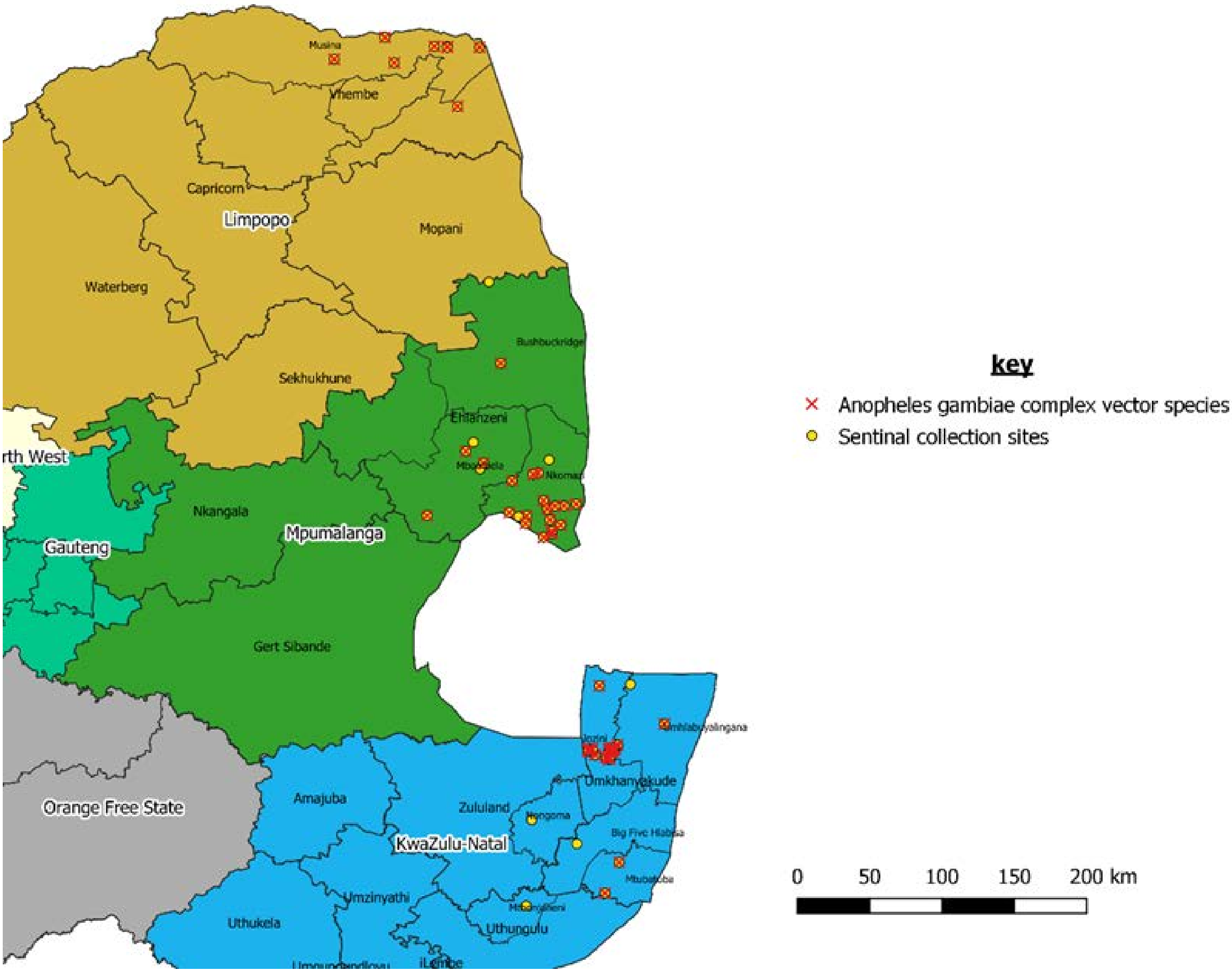

Figure 3: Sentinel sites in KwaZulu-Natal, Limpopo and Mpumalanga provinces from which samples of the malaria vectors *Anopheles arabiensis* and *An. merus* were collected, South Africa, 2018.

The secondary malaria vector species *An. vaneedeni* was collected from sentinel sites in all three endemic provinces while *An. parensis*, also a secondary vector, was collected in KwaZulu-Natal and Limpopo provinces (Table 1). Other potential malaria vector species within the *An. funestus* group that were collected from the provincial sentinel sites include *An. leesoni* and *An. rivulorum*. *Anopheles rivulorum* was collected in all three endemic provinces while *An. leesoni* was collected in KwaZulu-Natal and Limpopo provinces (Table 1).

The distribution of all known and suspected vector species within the *An. funestus* group is shown in Figure 4. Specimens of these species were collected in Jozini, Umhlabuyalingana and Mtubatuba in the Umkhanyakude District of KwaZulu-Natal Province, in Musina of the Vhembe District in Limpopo Province, and in Nkomazi of the Ehlanzeni district of Mpumalanga Province.

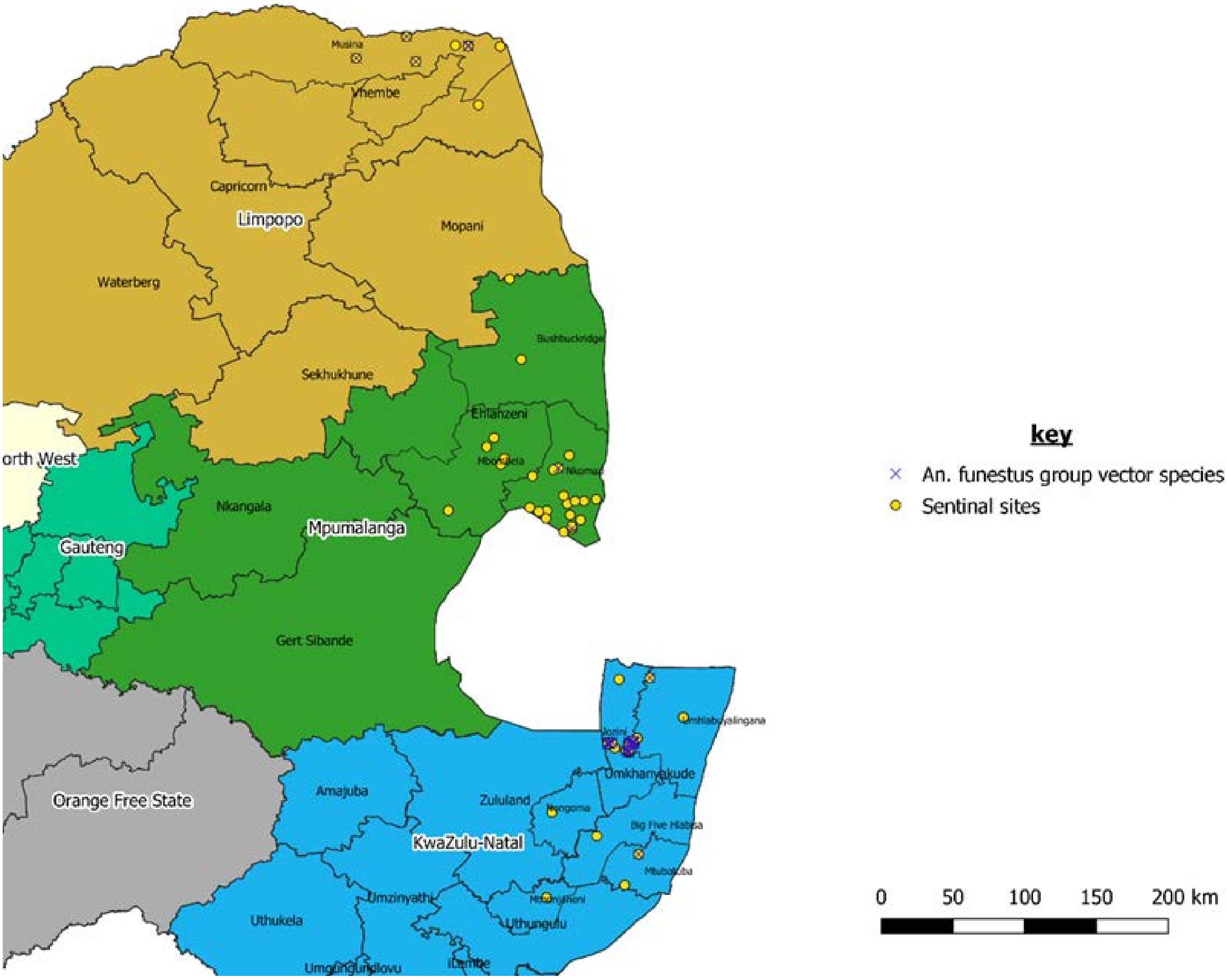

Figure 4: Sentinel sites in KwaZulu-Natal, Limpopo and Mpumalanga provinces from which samples of the known and potential secondary malaria vectors *Anopheles vaneedeni*, *An. parensis*, *An. rivulorum* and *An. leesoni* were collected, South Africa, 2018.

Anopheles coustani, *An. demeilloni*, *An. marshallii*, *An. pharoensis*, *An. rufipes* and *An. squamosus* have been incriminated as malaria vectors in other regions of Africa[8,9,10] but not in South Africa. *Anopheles coustani* was collected in KwaZulu-Natal and Limpopo provinces, *An. demeilloni* was collected in Limpopo Province, *An. marshallii* and *An. pharoensis* were collected in KwaZulu-Natal Province, *An. rufipes* was collected in KwaZulu-Natal and Limpopo provinces and *An. squamosus* was collected in all three endemic provinces (Table 1, Figure 2).

The number of anophelines collected by species and locality was highly variable across seasons. For example, *An. arabiensis* was most prevalent during late summer in KwaZulu-Natal Province while *An. merus* was most prevalent during spring and early summer in Mpumalanga Province (Figure 5). *Anopheles vaneedeni* and *An. parensis* predominated in late summer in Limpopo and KwaZulu-Natal provinces, respectively (Figure 6).

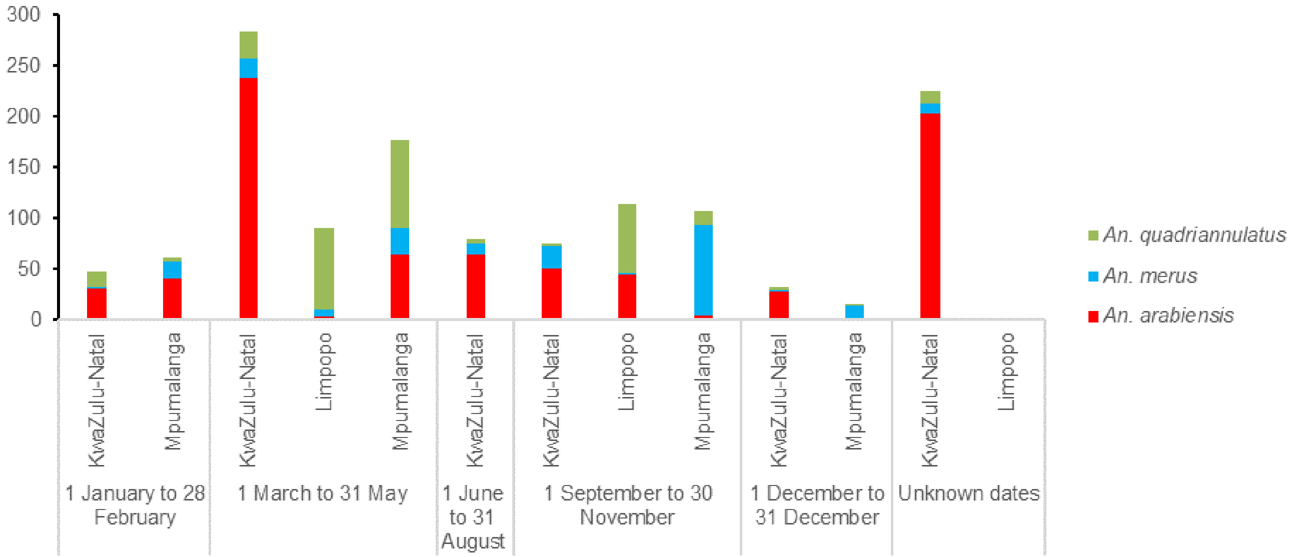

Figure 5: Proportional distribution (in absolute numbers) of *Anopheles gambiae* complex specimens collected by species, province and season, South Africa, 2018.

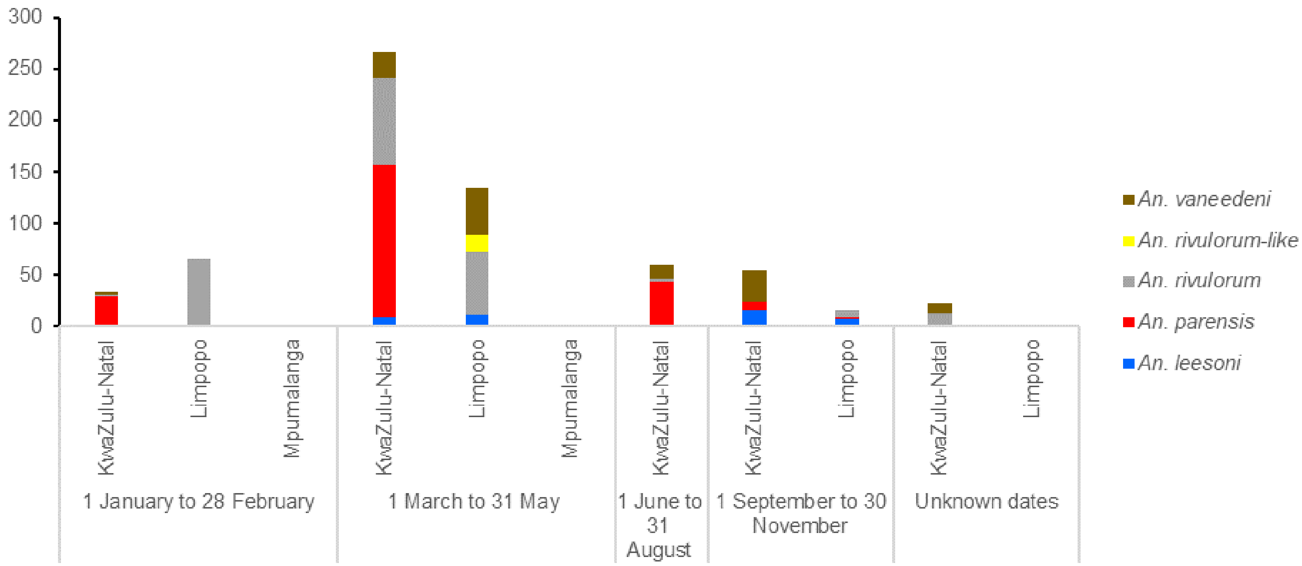

Figure 6: Proportional distribution (in absolute numbers) of *Anopheles funestus* group specimens collected by species, province and season, South Africa, 2018.

Discussion

In 2018, malaria vector surveillance revealed 18 *Anopheles* species across South Africa's three endemic provinces. These included species incriminated as vectors within South Africa as well as suspected vector species that have been incriminated in other African localities.

Anopheles arabiensis is a major malaria vector in South Africa[4] 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 is likely an important secondary malaria vector in South Africa[2] 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.[11]

Anopheles vaneedeni tends to rest outdoors and will readily feed on humans. It has been implicated as a secondary malaria vector in Mpumalanga and KwaZulu-Natal provinces[3] and likely plays an important role in residual transmission in South Africa.

Anopheles parensis has only recently been incriminated as a malaria vector.[12] Its contribution to residual malaria transmission in South Africa is likely to be minimal at best owing to its strong tendency to feed on livestock animals. This species will nevertheless feed on humans as well and will rest indoors and outdoors.

No *An. funestus* were collected during 2018. 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.[2] 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.[2] However, the possibility of transmission by this species in the border regions of Limpopo cannot be ruled out. Other members of the *An. funestus* group detected during 2018 include *An. leesoni*, *An. rivulorum* and *An. rivulorum*-like. Of these, only *An. rivulorum* has been implicated as a minor malaria vector in East Africa.

Other species that occur in South Africa and that have been incriminated as malaria vectors in various African localities include *An. marshallii*, *An. coustani*, *An. demeilloni*, *An. pharoensis*, *An. rufipes* and *An. squamosus*.[8,9,10] It is possible that one or more of these species plays a role in residual malaria transmission in South Africa.

Relative *Anopheles* population densities tend to fluctuate between seasons and are generally highest during the summer months congruent with increased rainfall.[4] These increased densities coincide with South Africa's summer malaria season because greater numbers of vector mosquitoes invariably translate into higher rates of transmission assuming there are adequate parasite populations.

Conclusion & recommendations

Several anophelines, including malaria vector species, occur in the north-eastern Lowveld regions of South Africa, with their relative abundances varying considerably by season. Despite coordinated provincial IRS programmes that usually achieve high spray coverage rates (80% or more of targeted structures in endemic areas), populations of these species persist and at least four of them - *An. arabiensis*, *An. merus*, *An. vaneedeni* and *An. parensis* – have previously been implicated in ongoing residual transmission in South Africa (tentative in the cases of *An. merus* and *An. parensis*). The reasons for this are multiple and certainly include outdoor-biting and outdoor-resting components of these species.

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
- Larval source management[13], including the treatment of winter breeding sites, be implemented and maintained so as to enhance the effect of IRS in high incidence areas
- Insecticide resistance management practices be maintained and periodically revised based on surveillance information

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