MALARIA VECTOR SURVEILLANCE REPORT, SOUTH AFRICA, JANUARY – DECEMBER 2019

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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. There were 13780 malaria cases resulting in 79 confirmed deaths in South Africa in 2019. Vector surveillance in collaboration with the National Institute for Communicable Diseases (NICD) during 2019 revealed the presence of four malaria vector species - *Anopheles arabiensis* (n=3,054, 60%), *An. merus* (n=427, 8%), *An. parensis* (n=424, 8%) and *An. vaneedeni* (n=141, 6%). These have previously been shown to contribute to ongoing residual malaria transmission in South Africa. Several closely related non-vector *Anopheles* species were also collected. The specimens analysed were collected from KwaZulu-Natal (85%, n=4,352) and Mpumalanga (15%, n=773) 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 continue to be used as a complimentary method to enhance the effect of IRS in high incidence areas. In the

context of the current COVID-19 pandemic, it is further recommended that all vector malaria control activities be conducted especially timeously and efficiently. This will reduce the risk of co-infection in affected communities and reduce malaria-related hospitalizations.

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 2019 (13,780 cases) was substantially lower than that recorded in 2018 (18,638 cases), but still higher than that of 2016 (9,478 cases).[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 to inform best practices for control. This is especially pertinent in terms of South Africa's malaria elimination agenda[7] and the current COVID-19 pandemic, during which it is especially important to reduce disease burden as far as possible. Currently, surveillance is routinely conducted by the entomology teams of Mpumalanga, KwaZulu-Natal and Limpopo provinces with support from partner institutions including the National Institute for Communicable Diseases (NICD), the Wits Research Institute for Malaria (WRIM) of the

University of the Witwatersrand, the Institute for Sustainable Malaria Control of the University of Pretoria, and the South African Medical Research Council.

This report summarises malaria vector surveillance in South Africa in 2019 based on specimens referred to the Vector Control Reference Laboratory (VCRL) of the Centre for Emerging Zoonotic and Parasitic Diseases (CEZPD), NICD.

Methods

During 2019, *Anopheles* mosquitoes were collected from sentinel sites in KwaZulu-Natal 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 2019.

Adult *Anopheles* mosquitoes were collected by human-baited net traps, human landing catches, CO_2 net traps, and outdoor placed clay pots, modified buckets and tyres. 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 17025:2017 standard was used to ensure the quality of results.

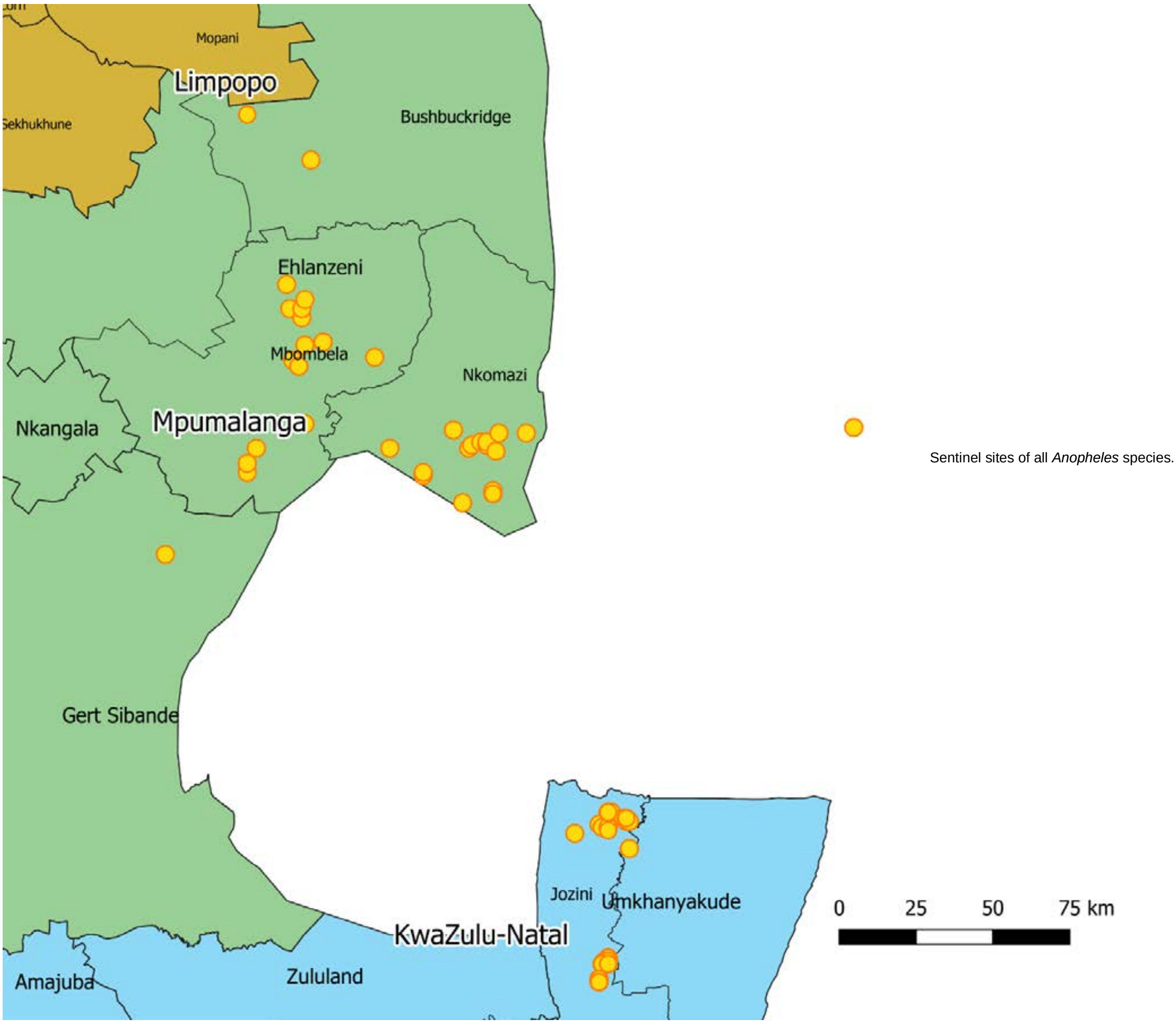

Figure 1. Sentinel sites in KwaZulu-Natal and Mpumalanga provinces from which *Anopheles* species were collected, South Africa, 2019.

Results

A total of 5,125 *Anopheles* mosquitoes was collected from sentinel sites in the Umkhanyakude district of KwaZulu-Natal Province and the Ehlanzeni and Gert Sibande districts of Mpumalanga Province. Most of the specimens were collected from KwaZulu-Natal (85%, n=4,352) followed by Mpumalanga (15%, n=773) (Table 1). These were subsequently identified as members of the *An. gambiae* complex (70%, n=3,574), *An. funestus* group (15%, n=760) or other *Anopheles* species (15%, n=791). *Anopheles arabiensis* predominated the collections (60%, n=3,054) although substantial numbers of *An. marshallii group, An. merus*, *An. parensis*, *An. rivulorum* and *An. vaneedeni* were also obtained (Table 1).

Table 1. Numbers of *Anopheles* specimens collected by species and province, South Africa, 2019.

***Anopheles* species complex, group or other**	***Anopheles* species**	**KwaZulu-Natal**	**Mpumalanga**	**Total**
***An. gambiae* complex**	*An. arabiensis*	2,765	289	3,054
	An. merus	104	323	427
	An. quadriannulatus	23	70	93
***An. funestus* group**	*An. leesoni*	45	8	53
	An. parensis	424		424
	An. rivulorum	112	30	142
	An. vaneedeni	125	16	141
Other *Anopheles* species	*An. coustani*	76		76
	An. caliginosus	1		1
	An. demeilloni	6		6
	An. listeri		23	23
	An. maculipalpis	4	4	8
	An. marshallii group	566		566
	An. pharoensis	17		17
	An. pretoriensis	33	9	42
	An. rufipes	40	1	41
	An. schwetzi	1		1
	An. squamosus	6		6
	An. tenebrous	2		2
	An. ziemanni	2		2
Total		4,352	773	5,125

The malaria vectors *An. arabiensis* and *An. merus* (members of the *An. gambiae* species complex) were collected from sentinel sites in both endemic provinces (Figure 2). In KwaZulu-Natal Province, populations of these species were found in the Jozini, Umhlabuyalingana and Mtubatuba municipalities of the Umkhanyakude District. In Mpumalanga, populations of these species were found in Nkomazi, Bushbuckridge and Mbombela of the Ehlanzeni District and in the Gert Sibande District.

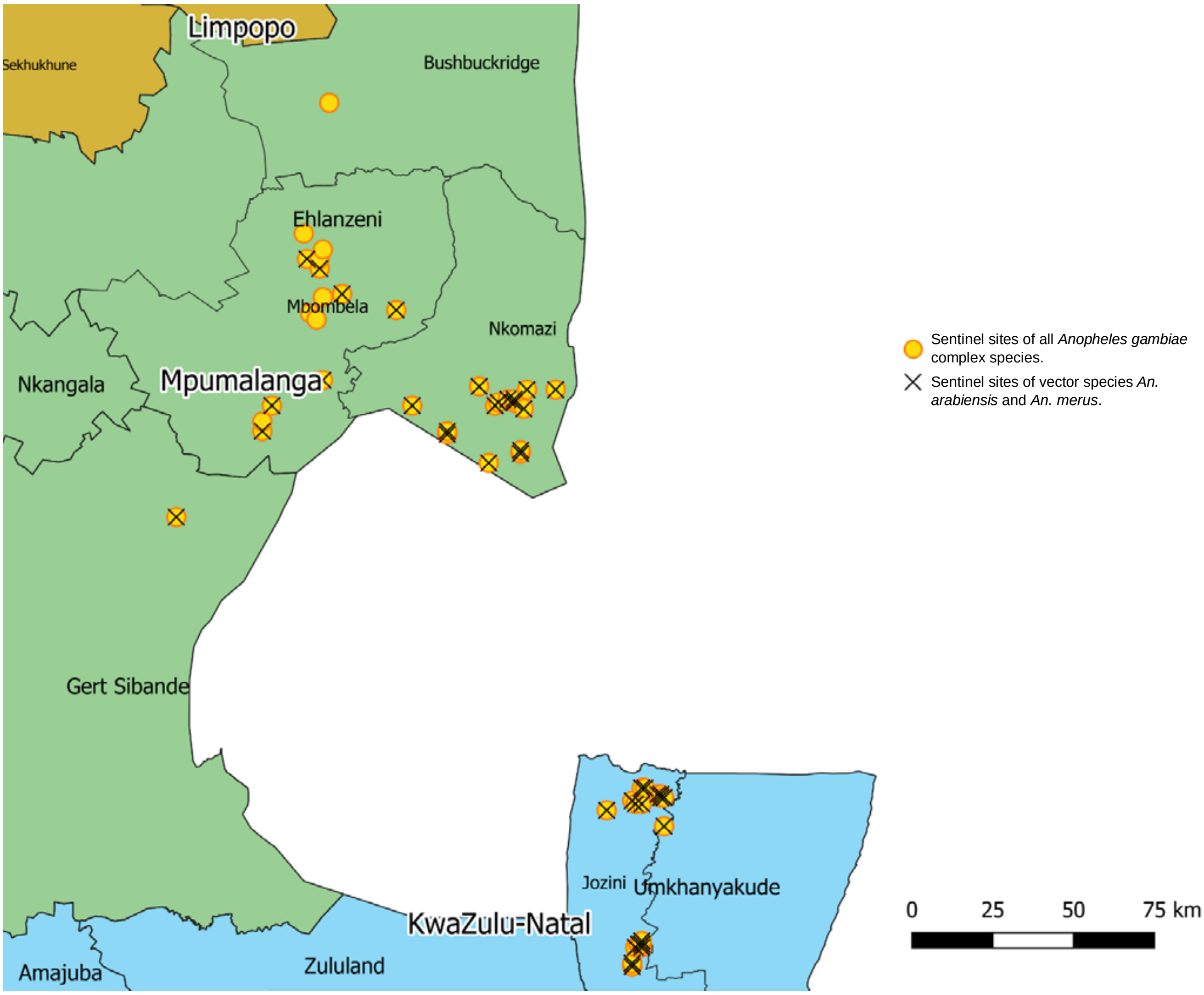

Figure 2. Sentinel sites in KwaZulu-Natal and Mpumalanga provinces from which samples of *Anopheles gambiae* complex species (yellow circle) were collected. Those sites from which the malaria vectors *An. arabiensis* and *An. merus* (black "x") were collected are indicated by an X, South Africa, 2019.

The secondary malaria vector species *An. vaneedeni* [3] was collected from sentinel sites in both provinces while *An. parensis*, also a secondary vector [8], was collected only in KwaZulu-Natal (Table 1). Other potential malaria vector species within the *An. funestus* group that were collected from sentinel sites in both provinces include *An. leesoni* and *An. rivulorum* (Table 1). The distribution of all known and suspected vector species within the *An. funestus* group is shown in Figure 3. Specimens of these species were collected in Jozini in the Umkhanyakude District of KwaZulu-Natal Province and in Nkomazi and Bushbuckridge of the Ehlanzeni District of Mpumalanga Province.

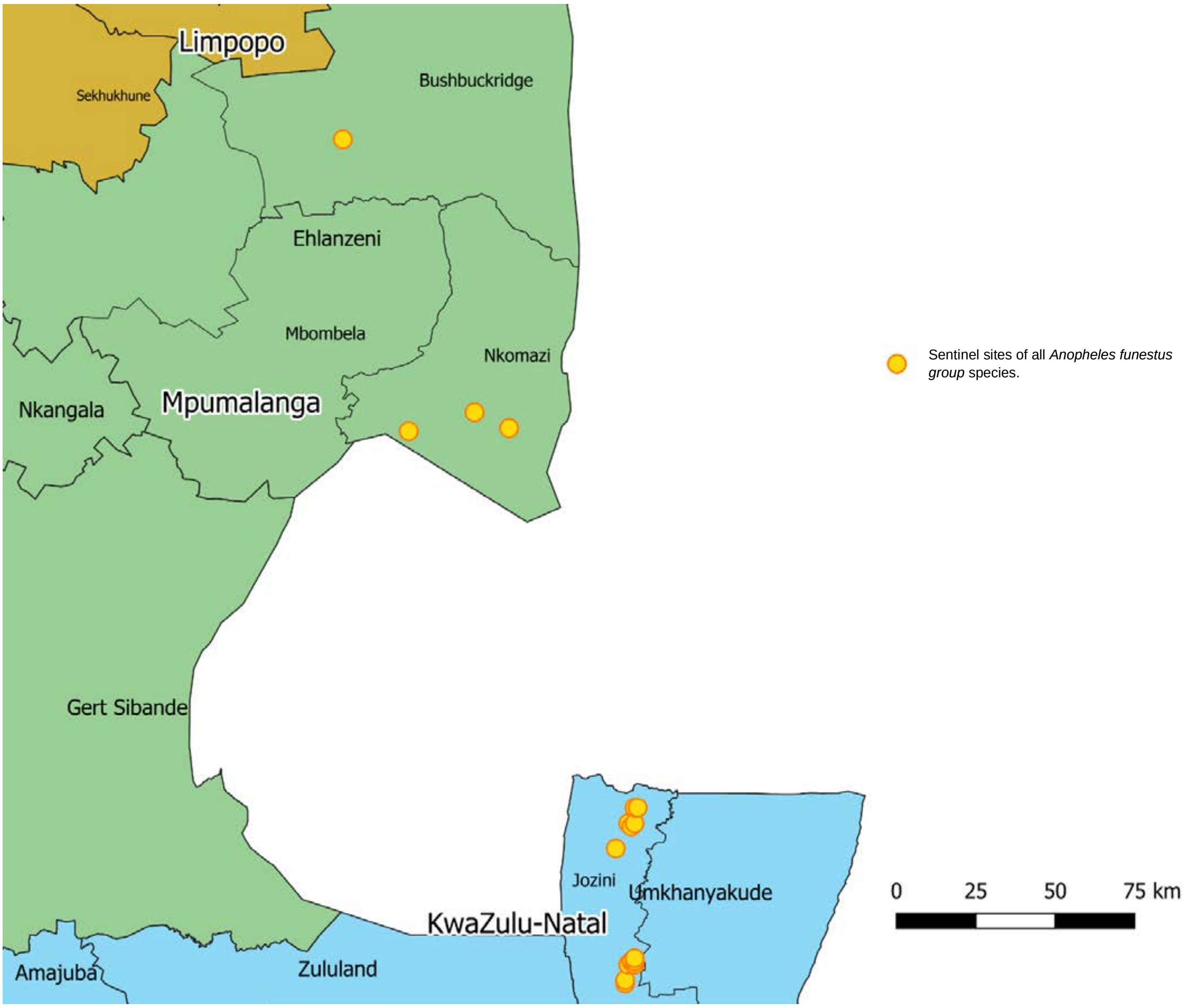

Figure 3. Sentinel sites in KwaZulu-Natal and Mpumalanga provinces from which samples of the known and potential secondary malaria vectors *Anopheles vaneedeni*, *An. parensis*, *An. rivulorum* and *An. leesoni* were collected, South Africa, 2019.

Anopheles coustani, *An. demeilloni*, *An. marshallii* group, *An. pharoensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni* have been incriminated as malaria vectors in other regions of Africa[9,10,11,12] but not in South Africa. The distribution of these potential vector species is shown in Figure 4. Specimens of these species were collected in Jozini in the Umkhanyakude District of KwaZulu-Natal Province and in Nkomazi and Bushbuckridge of the Ehlanzeni District of Mpumalanga Province.

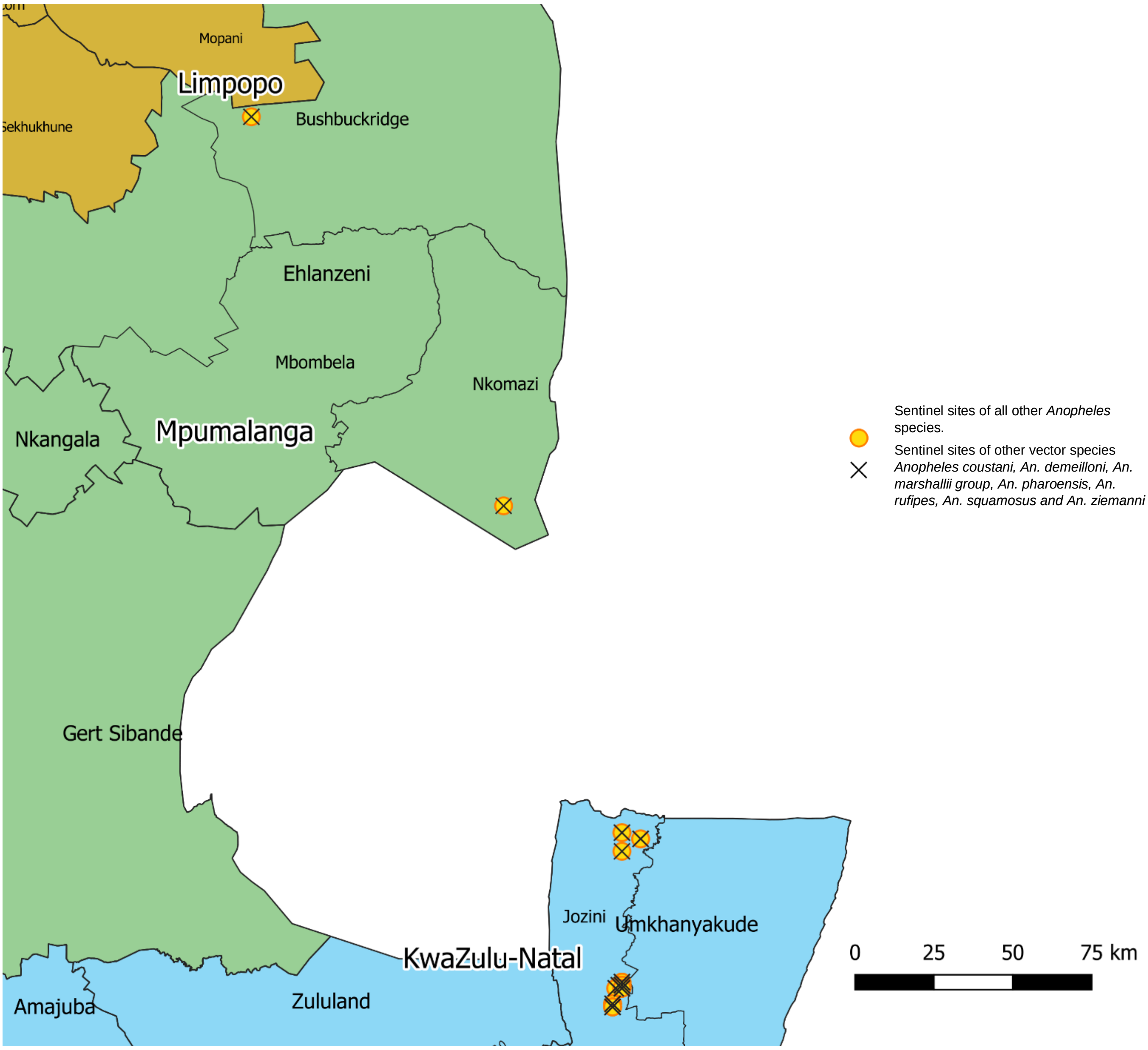

Figure 4. Sentinel sites in KwaZulu-Natal and Mpumalanga provinces from which samples of all other *Anopheles* species (yellow circle) were collected. Sites from which the potential secondary malaria vectors *Anopheles coustani*, *An. demeilloni*, *An. marshallii* group, *An. pharoensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni* were collected are indicated by an X, South Africa, 2019.

The number of anophelines collected by species and locality was highly variable across seasons. For example, *An. arabiensis* was most prevalent during spring and summer in KwaZulu-Natal Province while *An. merus* was particularly prevalent during winter and spring in Mpumalanga Province (Figure 5). *Anopheles parensis* and *An. rivulorum* were most common during summer in KwaZulu-Natal and *An. rivulorum* predominated in autumn in Mpumalanga (Figure 6). There was a comparatively high prevalence of *An. marshallii* group through most of the year in KwaZulu-Natal (Figure 7).

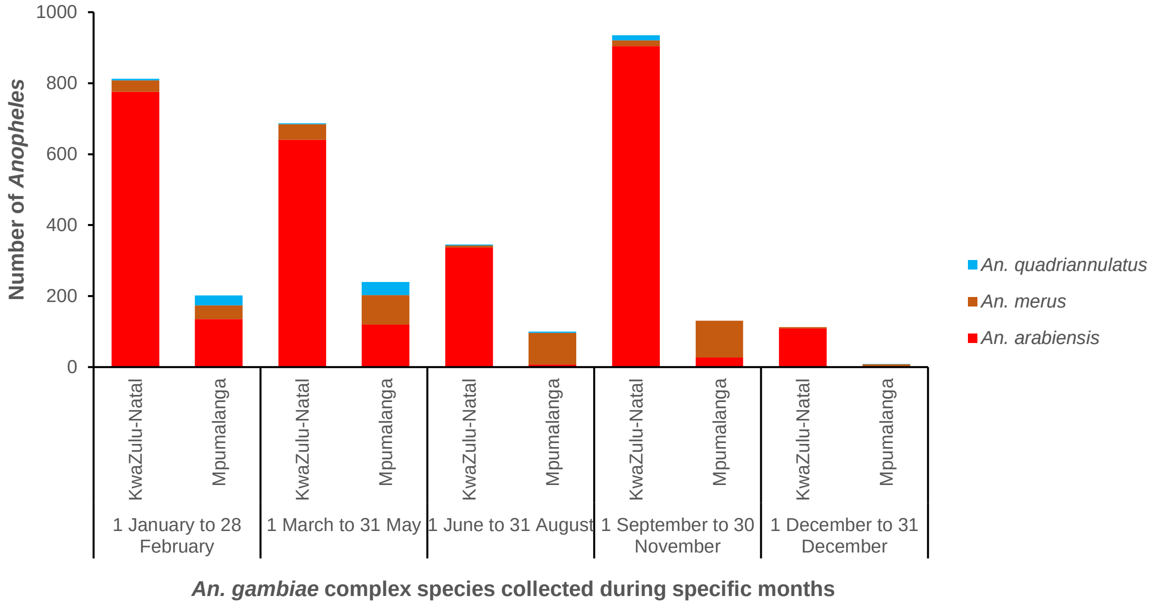

Figure 5. Distribution (in absolute numbers) of *Anopheles gambiae* complex specimens collected by species, province and season, South Africa, 2019.

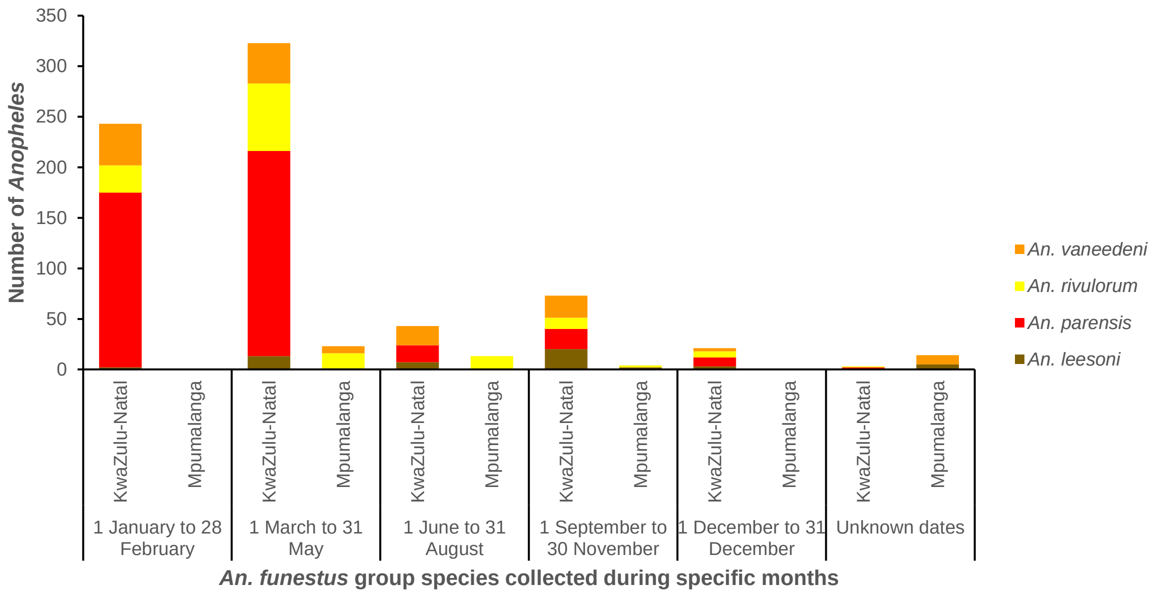

Figure 6. Distribution (in absolute numbers) of *Anopheles funestus* group specimens collected by species, province and season, South Africa, 2019.

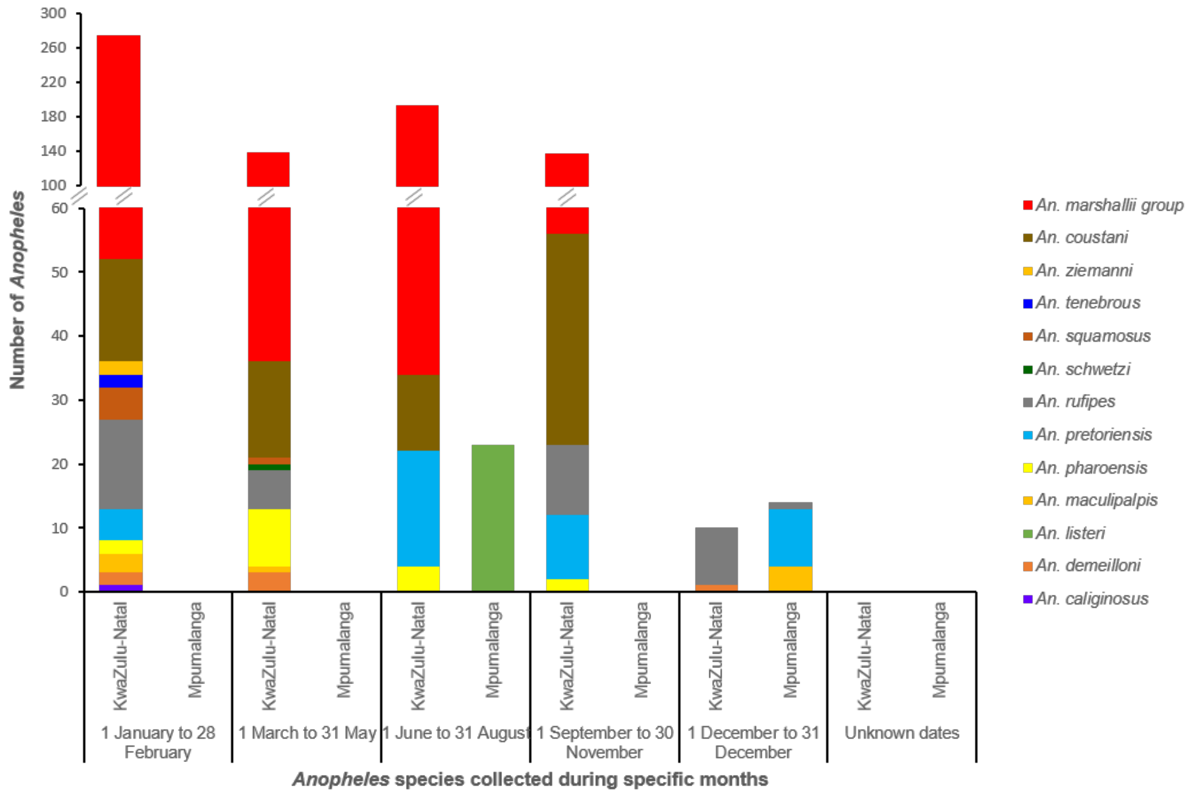

Figure 7. Distribution (in absolute numbers) of miscellaneous *Anopheles* specimens collected by species, province and season, South Africa, 2019.

Discussion

Malaria vector surveillance during 2019 in the KwaZulu-Natal and Mpumalanga provinces of South Africa revealed 19 *Anopheles* species. These included species incriminated as vectors within South Africa as well as suspected vector species that have been incriminated in other African countries.

Anopheles arabiensis 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.[4]

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 what were likely fresh-water breeding sites (salinity was not tested in these sites at time of collection). Data from Mpumalanga Province suggest that this species is increasing its inland range and abundance by adapting to breeding in fresh-water habitats.[13]

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 recently been incriminated as a malaria vector in South Africa.[8] Its contribution to residual malaria transmission is however 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.

Although no *An. funestus* were collected in KwaZulu-Natal and Mpumalanga provinces during 2019, there is a recent record of this species in Limpopo Province.[14] 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, in light of the recent detection of *An. funestus* in Limpopo, the possibility of transmission by this species in the border regions of the Vhembe and Mopani districts cannot be ruled out. Other members of the *An. funestus* group detected during 2019 include *An. leesoni* and *An. rivulorum*. Of these, both have been implicated as a minor malaria vector in East Africa [9].

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*, *An. squamosus* and *An. ziemanni*.[9,10,11,12] 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[15], including the treatment of winter breeding sites, be 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
- In the context of the current COVID-19 pandemic, malaria control activities should be conducted especially timeously and efficiently. This will reduce the risk of co-infection in affected communities and reduce malaria-related hospitalizations

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 and all members of the South African Malaria Elimination Committee (SAMEC) are especially thanked for their support for vector surveillance. These activities were sponsored by the Mpumalanga and KwaZulu-Natal Malaria Control Programmes, the National Institute for Communicable Diseases, 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.

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PUBLIC HEALTH SURVEILLANCE BULLETIN

The Public Health Surveillance Bulletin is published by the National Institute for Communicable Diseases (NICD) of the National Health Laboratory Service (NHLS)

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