MALARIA VECTOR SURVEILLANCE REPORT, SOUTH AFRICA, JANUARY – DECEMBER 2021

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Summary

Malaria in South Africa is seasonal and primarily occurs in the Limpopo, Mpumalanga and KwaZulu-Natal provinces. Malaria vectors are controlled by indoor spraying of residual insecticides (IRS) and limited larval source management. Vector surveillance in collaboration with the National Institute for Communicable Diseases (NICD) during 2021 revealed the presence of four malaria vector species - *Anopheles arabiensis* (n=4,873, 43%), *An. merus* (n=709, 6%), *An. parensis* (n=1,175, 10%) and *An. vaneedeni* (n=335, 3%). 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 (69.7%, n=7,967), Mpumalanga (6.5%, n=747) and Limpopo (23.7%, n=2,714) provinces. The surveillance information by province and municipality shows that IRS-based vector control needs to be maintained at a high rate of coverage in high-incidence areas, and that spraying should ideally be completed before the onset of each malaria season. Consideration can be given to a more targeted or reactive approach in areas where no local cases have been recorded for three or more years. Given that all sporozoite positive (and therefore malaria infective) adult *Anopheles* females collected in the recent years 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 areas where locally-acquired cases occur and in other receptive areas at risk for malaria. Consideration should also be given to the distribution of dual active ingredient insecticide treated bed nets to migrant / mobile communities that are not protected by the IRS programmes.

Introduction

South Africa's malaria affected areas include the low altitude border regions of Limpopo, Mpumalanga and KwaZulu-Natal (KZN) provinces. These regions typically experience active malaria transmission, especially during the peak malaria season that spans the summer months of November to April. The total number of malaria cases in the 2020/2021 malaria season in South Africa was 4961, while the 2021/2022 malaria season saw 2386 cases.[1]

Each of South Africa's malaria endemic provinces have developed well-coordinated malaria prevention 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 less susceptible to indoor applications of insecticide.[3,4,5] In addition, populations of the major malaria vector species, *Anopheles funestus* and *An. arabiensis*, have developed resistance to insecticides, especially in northern KwaZulu-Natal.[2,6] The pyrethroid resistance phenotype in *An. arabiensis* in this region is however of low intensity currently and is not considered to be operationally significant yet. This is in contrast to the pyrethroid-carbamate resistance profile in *An. funestus* which is of high intensity, highly significant epidemiologically and was at least partly causative of the malaria epidemic experienced in South Africa during the period 1996 to 2000.[7]

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 pertinent in terms of South Africa's malaria elimination agenda[8] and the ongoing COVID-19 pandemic, making it especially important to reduce disease burden as far as possible.[9] 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 UP Institute for Sustainable Malaria Control (UP ISMC) of the University of Pretoria, and the South African Medical Research Council.

This report summarises malaria vector surveillance in South Africa in 2021 based on specimens referred to the Vector Control Reference Laboratory (VCRL) of the Centre for Emerging Zoonotic and Parasitic Diseases (CEZPD), NICD, as well as specimens collected and analysed by personnel from the University of Pretoria.

Methods

Anopheles mosquitoes were collected from sentinel sites in KwaZulu-Natal, Mpumalanga and Limpopo provinces (Figure 1). These specimens were either collected by VCRL and UP ISMC, or referred to the VCRL by partner institutions and provincial malaria control programme entomology teams from January to December 2021.

Adult *Anopheles* mosquitoes were collected by human-baited net traps, human landing catches, cattle kraal, house search, CDC-light traps, BG-sentinel traps, CO_2 net traps, and outdoor placed clay pots, drums, cloth tubes, 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 microcentrifuge 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 by VCRL and UP ISMC.[10,11,12] An ELISA assay was used to detect the presence of *Plasmodium falciparum* circumsporozoites in selected female specimens.[13,14] The VCRL is a SANAS accredited laboratory and the ISO 17025:2017 standard was used to ensure the quality of results of all specimens received and analysed.

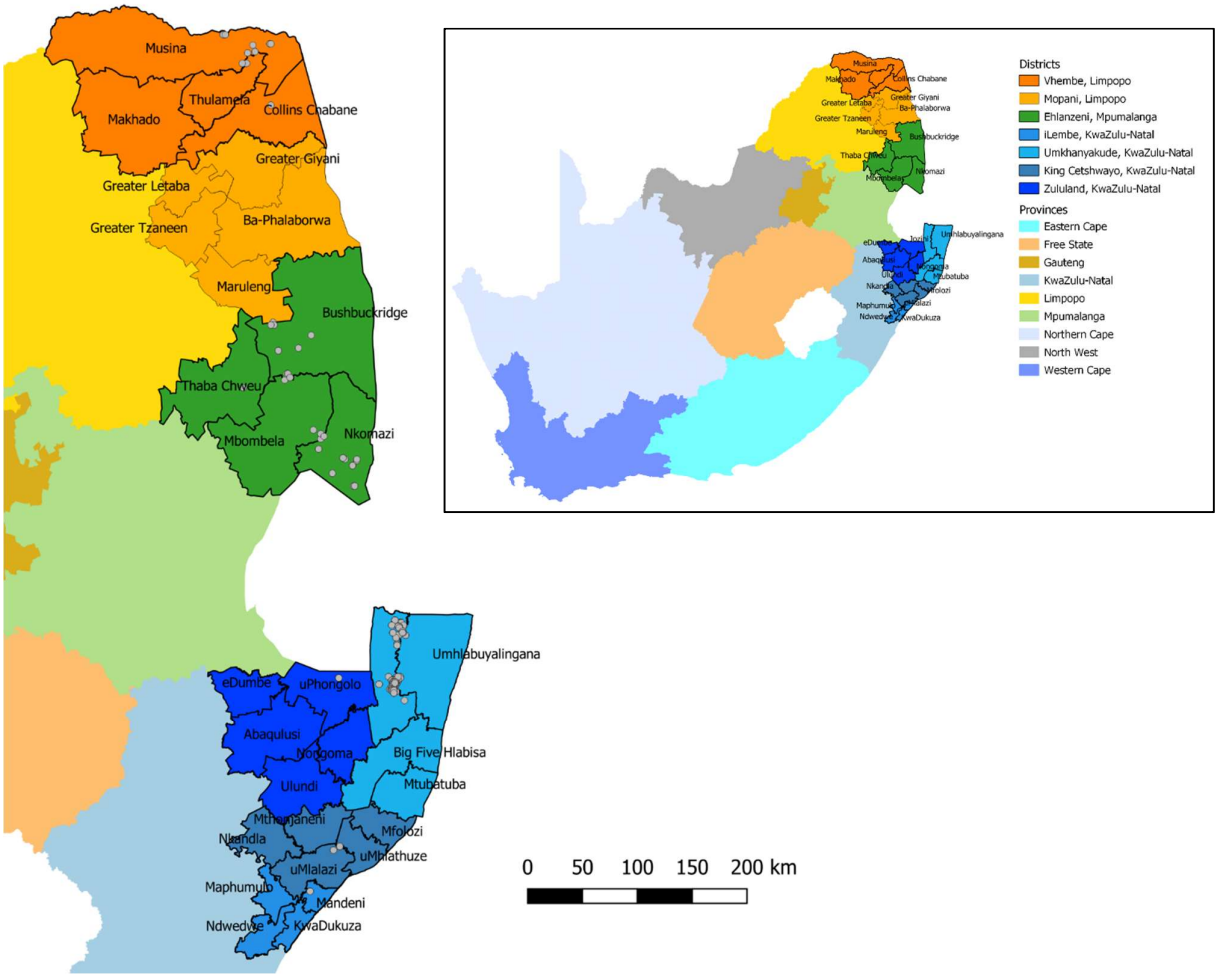

Figure 1. Sentinel sites (grey dots) in KwaZulu-Natal, Mpumalanga and Limpopo provinces from which *Anopheles* specimens were collected, South Africa, 2021.

Results

A total of 11,428 *Anopheles* mosquitoes was collected from sentinel sites in the Ilembe, Umkhanyakude, King Cetshwayo and Zululand districts of KwaZulu-Natal Province, the Ehlanzeni district of Mpumalanga Province and the Vhembe and Mopani districts of Limpopo Province. Most of the specimens were collected from KwaZulu-Natal (69.7%, n=7,967) followed by Limpopo (23.7%, n=2,714) and Mpumalanga (6.5%, n=747) provinces (Table 1). These were subsequently clustered as either *An. gambiae* complex (52%, n=5,990), *An. funestus* group (18%, n=2,007) or other *Anopheles* species (30%, n=3,431). *Anopheles arabiensis* predominated the collections (43%, n=4,873), especially in KwaZulu-Natal, although substantial numbers of *An. merus*, *An. parensis*, *An. listeri*, *An. marshallii* complex and *An. pretoriensis* were also collected. *Anopheles merus* and *An. listeri* predominated in

Mpumalanga and Limpopo provinces, respectively (Table 1). None of the 136 adult female mosquitoes from KZN selected for detection of *P. falciparum* circumsporozoites by ELISA were positive (Table 2)

Table 1. Numbers of *Anopheles* specimens collected by species and province, South Africa, 2021.

***Anopheles* species complex, group or other**	**Species**	**KwaZulu-Natal**	**Mpumalanga**	**Limpopo**	**Total**
***An. gambiae* complex**	*An. arabiensis*	4,715	105	53	4,873
	An. merus	244	462	3	709
	An. quadriannulatus	59	99	250	408
***An. funestus* group**	*An. leesoni*	163	1	157	321
	An. parensis	1,175			1,175
	An. rivulorum	110		39	149
	An. rivulorum-like	0		27	27
	An. vaneedeni	329	5	1	335
Other *Anopheles* species	*An. coustani*	129	9	75	213
	An. demeilloni	23		96	119
	An. gibbinsi			141	141
	An. listeri			721	721
	An. longipalpis		1		1
	An. maculipalpis	26	1		27
	An. marshallii complex	652			652
	An. natalensis			2	2
	An. pharoensis	85			85
	An. pretoriensis	3	15	615	633
	An. rhodesiensis			69	69
	An. rufipes	101	49	420	570
	An. squamosus	72			72
	An. tenebrous	72		43	115
	An. ziemanni	9		2	11
Total		7,967	747	2,714	11,428

Table 2. Numbers of *Anopheles* female specimens collected as adults from KwaZulu-Natal Province in 2021, and tested for the presence of *Plasmodium falciparum* circumsporozoites by ELISA.

***Anopheles* species complex, group or other**	**Species**	**Number of species tested negative for the presence of *P. falciparum***	**Number of species tested positive for the presence of *P. falciparum***
***An. gambiae* complex**	*An. arabiensis*	8	0
	An. merus	1	0
Other *Anopheles* species	*An. coustani*	17	0
	An. demeilloni	1	0
	An. maculipalpis	1	0
	An. marshallii complex	1	0
	An. pharoensis	32	0
	An. pretoriensis	2	0
	An. rufipes	35	0
	An. squamosus	38	0
Total		136	0

The malaria vectors *An. arabiensis* and *An. merus* (members of the *An. gambiae* species complex) were collected from sentinel sites in all the endemic provinces (Figure 2). In KwaZulu-Natal Province, populations of these species were found in the Jozini and Umhlabuyalingana municipalities of the Umkhanyakude District, uPhongolo municipality of Zululand District and the uMlalazi municipalities of the King Cetshwayo District. In Mpumalanga, populations of these species were found in all the municipalities of the Ehlanzeni District. In Limpopo Province, these species were found in the Collins Chabane and Musina municipalities of the Vhembe district.

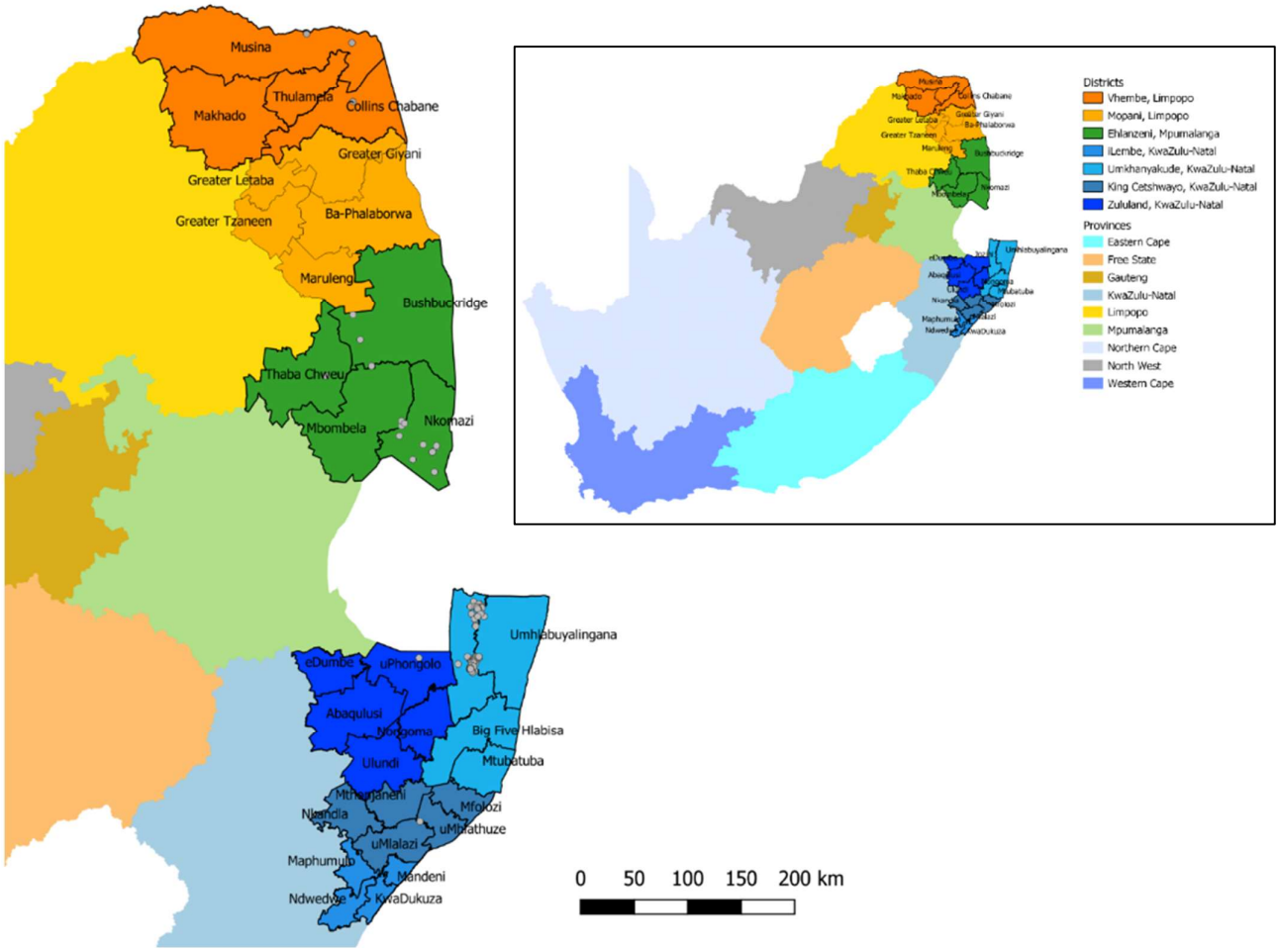

Figure 2. Sentinel sites (grey dots) in KwaZulu-Natal, Mpumalanga and Limpopo provinces from which samples of *Anopheles arabiensis* and *An. merus* (*Anopheles gambiae* complex) were collected, South Africa, 2021.

The potential secondary malaria vector species *An. vaneedeni* [3] was collected from sentinel sites in all three endemic provinces while *An. parensis*, also a potential secondary vector[15], was only collected in KwaZulu-Natal Province (Table 1). Other potential malaria vector species within the *An. funestus* group that were collected from sentinel sites in these three provinces included *An. leesoni* and *An. rivulorum* (Table 1). Collection sites for all known and suspected vector species within the *An. funestus* group are shown in Figure 3. Specimens of these species were collected in the Jozini and Umhlabuyalingana municipalities of the Umkhanyakude District, the uMlalazi municipality of the King Cetshwayo District and the Mandeni municipality of Ilembe District, KwaZulu-Natal Province, in Nkomazi and Bushbuckridge of the Ehlanzeni District of Mpumalanga Province and in the Musina and Thulamela municipalities of the Vhembe District of Limpopo Province.

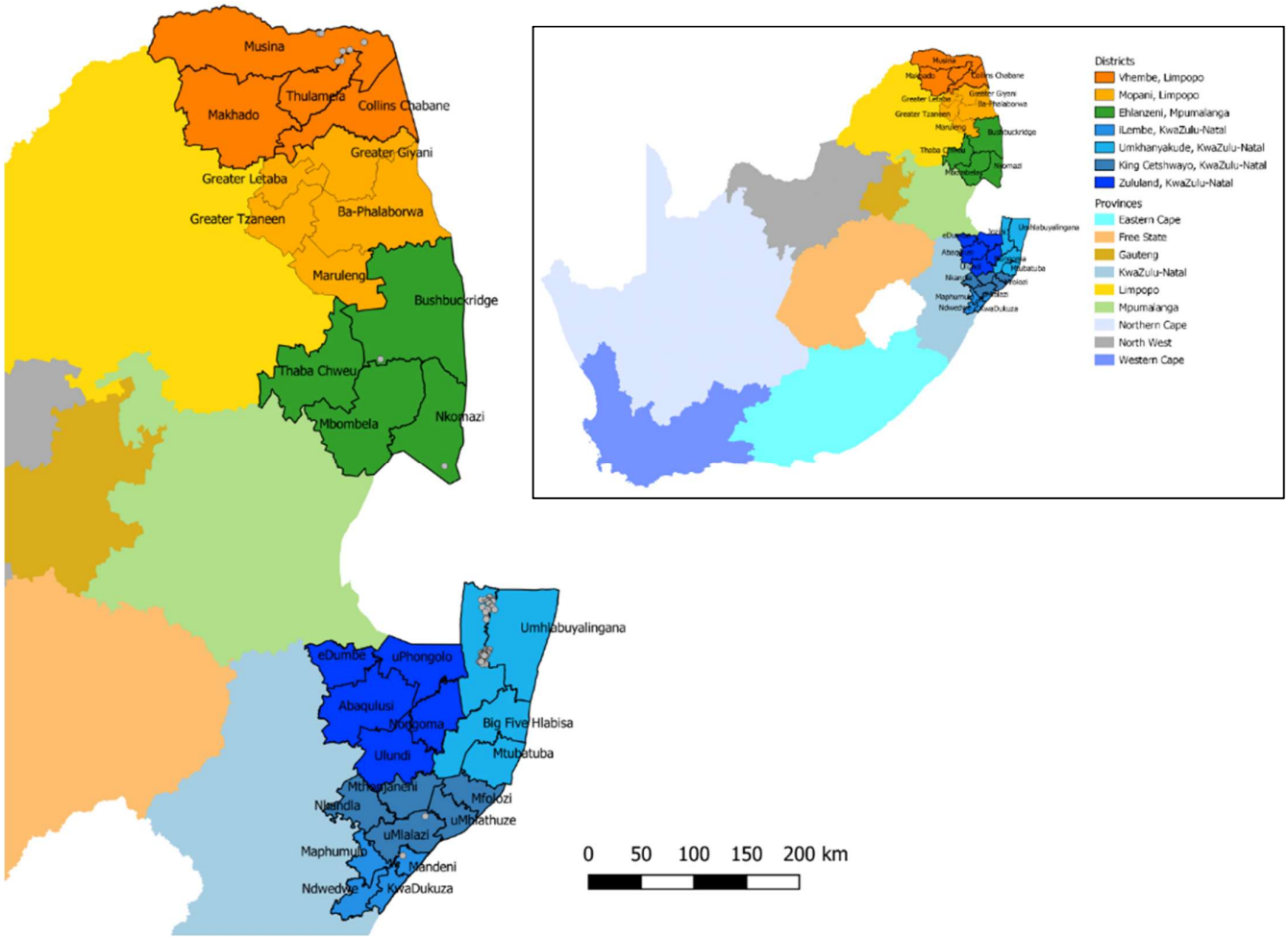

Figure 3. Sentinel sites (grey dots) in KwaZulu-Natal, Mpumalanga and Limpopo provinces from which samples of the known and potential secondary malaria vectors *Anopheles vaneedeni*, *An. parensis*, *An. rivulorum* and *An. leesoni* (*An. funestus* group) were collected, South Africa, 2021.

Anopheles coustani, *An. demeilloni*, *An. longipalpis*, *An. marshallii* complex, *An. pharoensis*, *An. pretoriensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni* have been incriminated as malaria vectors in other regions of Africa[16,17,18,19, 20] but not in South Africa. The distribution of these potential vector species is shown in Figure 4. Specimens of these species were collected in the Jozini and Umhlabuyalingana municipalities in the Umkhanyakude District as well as uPhongolo municipality of the Zululand district of KwaZulu-Natal Province, in Bushbuckridge and Nkomazi municipalities of the Ehlanzeni District of Mpumalanga Province and in the Musina and Thulamela municipalities of the Vhembe district of Limpopo Province.

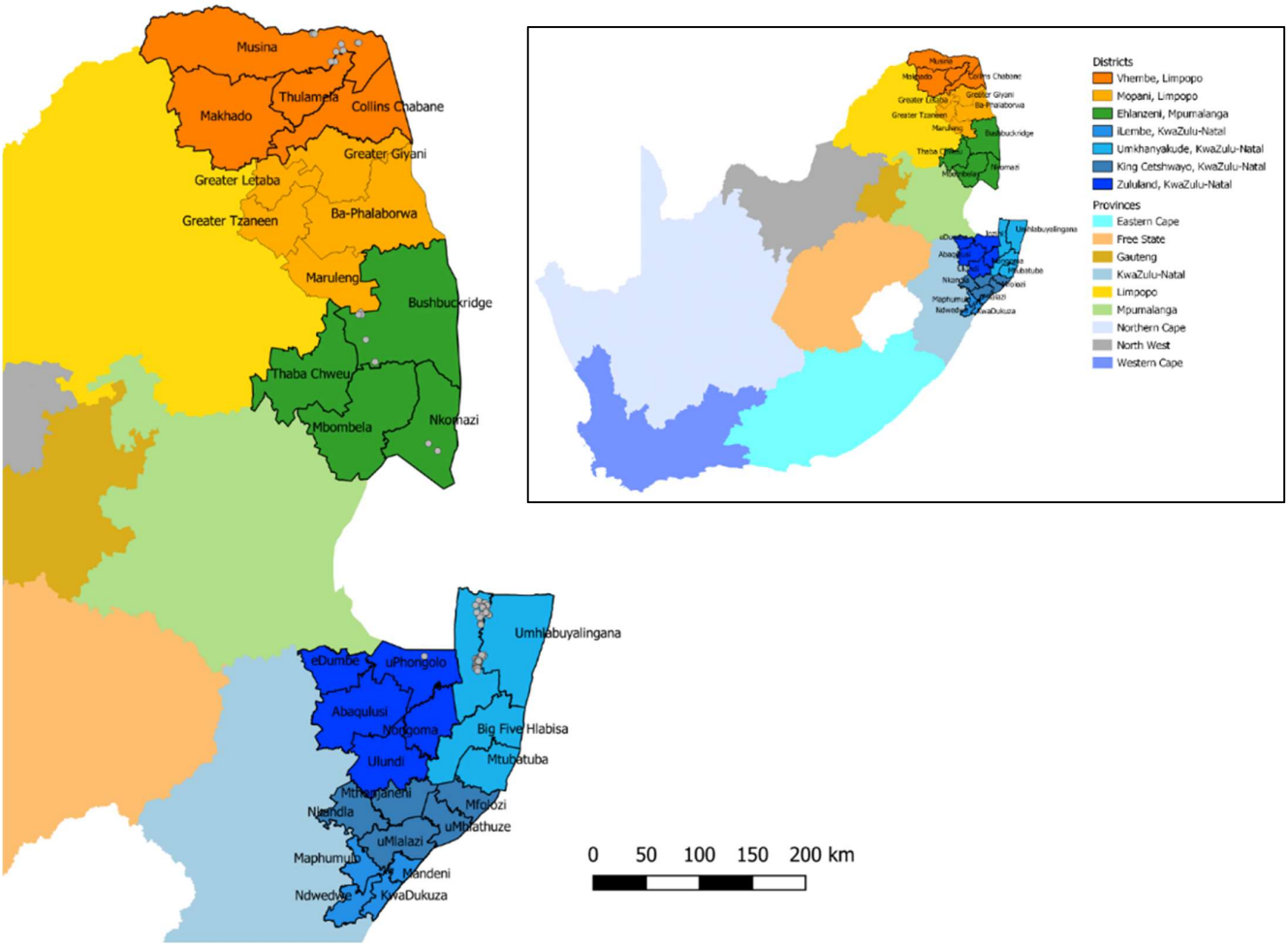

Figure 4. Sentinel sites (grey dots) in KwaZulu-Natal, Mpumalanga and Limpopo provinces from which samples of miscellaneous *Anopheles* species (species not belonging to the *An. gambiae* complex or *An. funestus* group) were collected. These sites included the collection of potential secondary malaria vectors *Anopheles coustani*, *An. demeilloni*, *An. longipalpis*, *An. marshallii* complex, *An. pharoensis*, *An. pretoriensis*, *An. rufipes*, *An. squamosus*, and *An. ziemanni*, South Africa, 2021.

The number of anophelines collected by species during specific seasons was highly variable across the three endemic provinces. For example, *An. arabiensis* was prevalent throughout the year in KwaZulu-Natal Province while *An. merus* was particularly prevalent throughout the year in the Mpumalanga Province (Figure 5). *Anopheles quadriannulatus* predominated the *Anopheles gambiae* complex collections from Limpopo Province during late summer (January to February) and autumn. *Anopheles parensis* was prevalent throughout the year in KwaZulu-Natal Province. Of the *An. funestus* group,

Anopheles vaneedeni predominated in Mpumalanga Province and *An. leesoni* dominated the collections in Limpopo Province during spring and early summer (December) (Figure 6). Miscellaneous *Anopheles* species collections in KwaZulu-Natal Province indicate that *Anopheles rufipes* and *An. pharoensis* predominated in late summer and autumn, respectively, while *An. marshallii* complex predominated in winter and spring (Figure 7). *Anopheles pretoriensis* and *An. rufipes* were evident in winter and spring, while in early summer *An. rufipes* predominated the collections of miscellaneous species in Mpumalanga Province. *Anopheles listeri* and *An. rufipes* predominated the miscellaneous species in spring and early summer, respectively, in Limpopo Province.

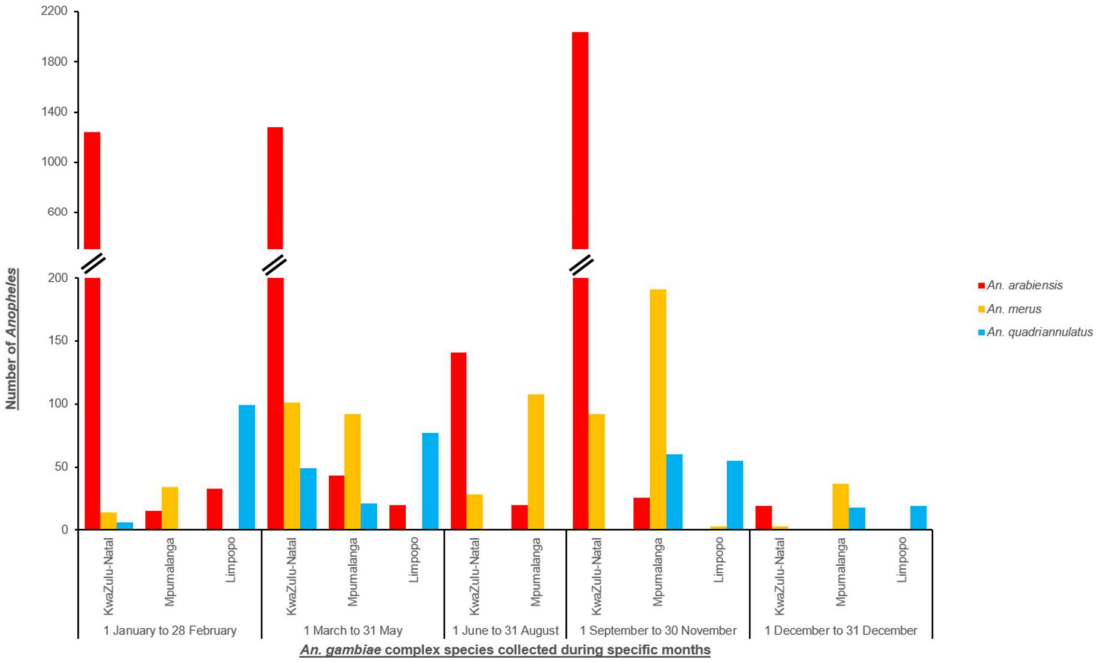

Figure 5. Distribution (in absolute numbers) of *Anopheles gambiae* complex specimens collected by species, province and season, South Africa, 2021.

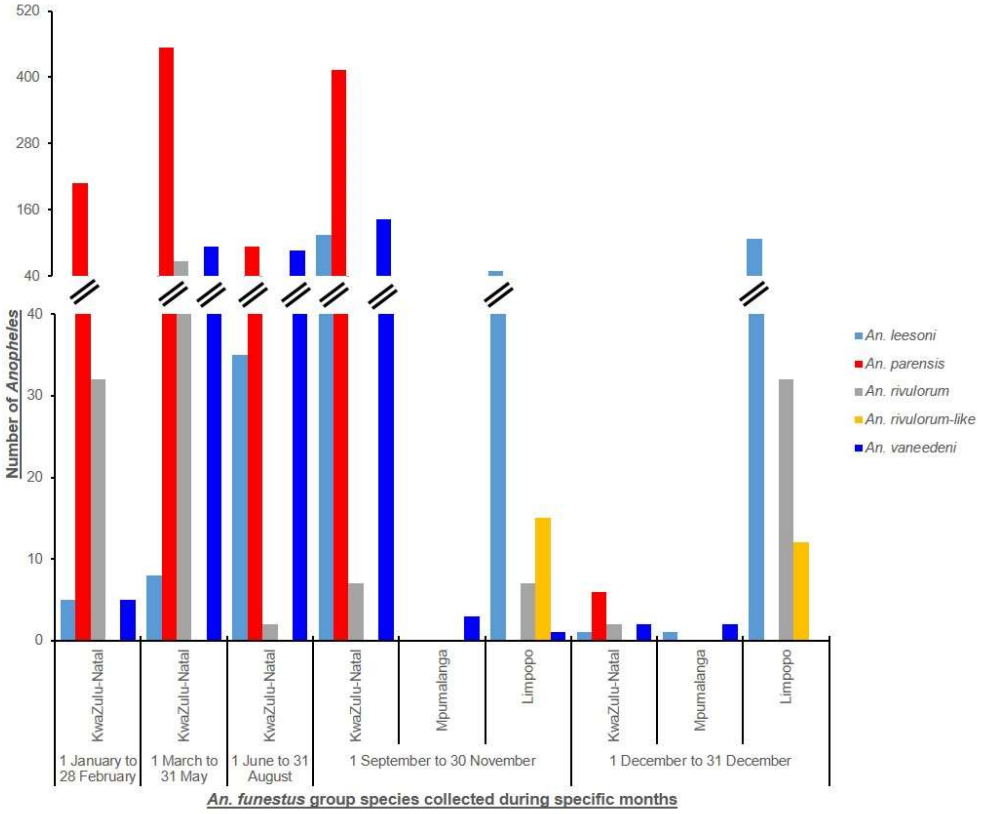

Figure 6. Distribution (in absolute numbers) of *Anopheles funestus* group specimens collected by species, province and season, South Africa, 2021.

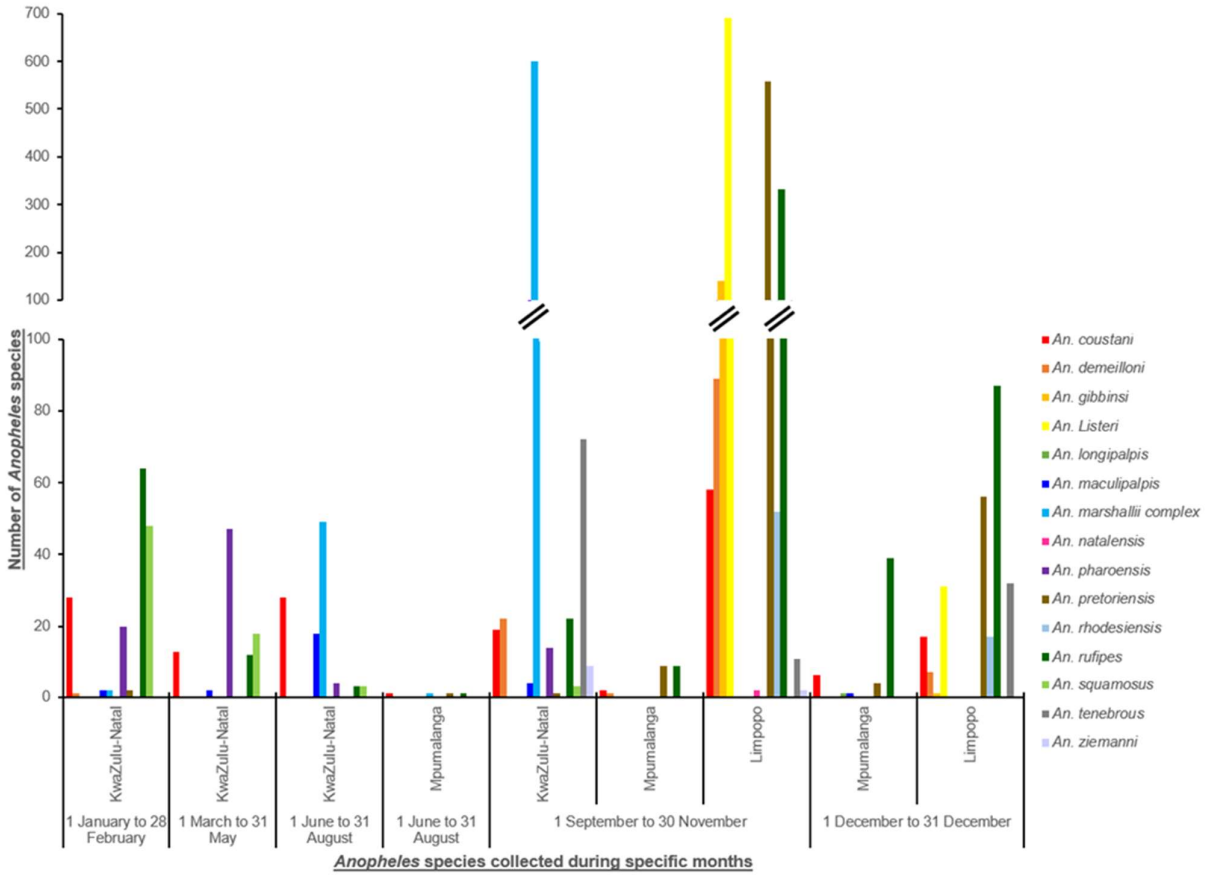

Figure 7. Distribution (in absolute numbers) of miscellaneous *Anopheles* specimens collected by species, province and season, South Africa, 2021

Anopheline specimens were collected either as larvae or adults. Collection methods and intensity of effort varied between the endemic provinces. In all three provinces, CO_2 tent traps and human landing catches were used to collect adult mosquitoes, and larvae were collected from breeding sites. CDC-light traps and CO_2 tent traps were primarily used to collect adult mosquitoes in Limpopo, yielding (53%, n=506) and (46%, n=443) respectively. In Mpumalanga, the majority of adult *Anopheles* were collected via human landing catches (65%, n=62). In KZN, the majority of adult *Anopheles* were collected using clay pots (64%, n=4,704) followed by tyre (23%, n=1,735), cloth tube (3.7%, n=276) and CO_2 tent trap (3.5%, n=256).

Within the *An. gambiae* complex, adult *An. arabiensis* and *An. merus* were collected using all the sampling methods listed in Table 3. *Anopheles arabiensis* adults were predominantly collected from clay pots (62%, n=2,786) and tyres (27%, n=1,199), while the *An. merus* adults were predominantly collected from clay pots (63%, n-=110) and human landing catches (22%, n=39) (Figure 8). Within the

An. funestus group, *An. parensis*, *An. vaneedeni*, *An. rivulorum* and *An. leesoni*, were collected by all the collection methods listed in Table 3 with the exception of male swarm collection. *Anopheles parensis* adults were predominantly collected via clay pots (67%, n=776) and tyres (27%, n=317), and 72% of the *An. vaneedeni* adults were collected from clay pots (n=235). *Anopheles leesoni* (n=120) and *An. rivulorum* (n=64) adults were also predominantly collected from clay pots (Figure 9).

The potential secondary malaria vectors *Anopheles coustani*, *An. demeilloni*, *An. longipalpis*, *An. marshallii* complex, *An. pharoensis*, *An. pretoriensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni* were collected using all the sampling methods listed in Table 3 with the exception of drum and male swarm collection. *An. coustani* (n=42), *An. demeilloni* (n=60) and *An. pretoriensis* (n=108) adults were predominantly collected from CDC-light traps. The *An. longipalpis* (n=1), *An. pharoensis* (n=39) and *An. squamosus* (n=27) adults were predominantly collected from CO_2 tent traps, while *An. marshallii* complex (n=488), *An. rufipes* (n=36) and *An. ziemanni* (n=5) were predominantly collected from clay pots (Figure 10).

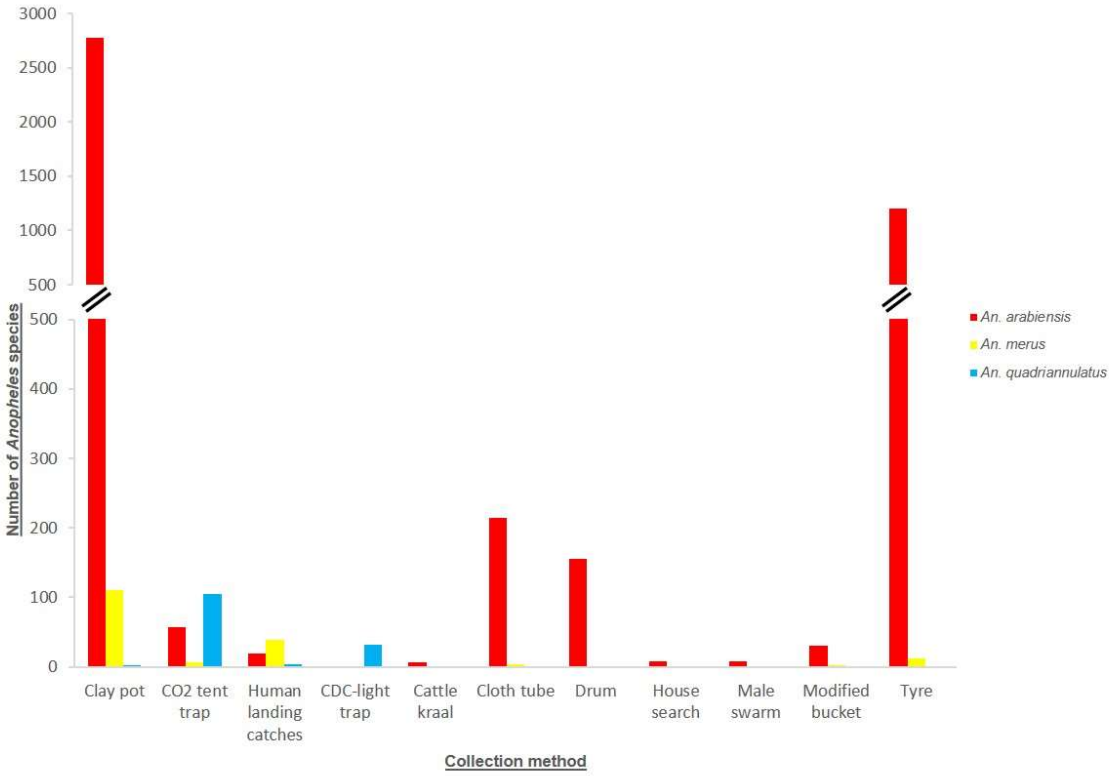

Figure 8. Distribution (in absolute numbers) of *Anopheles gambiae* complex specimens by sampling method, South Africa, 2021.

Table 3. Numbers of *Anopheles* specimens collected by sampling method, South Africa, 2021.

Anopheles species complex, group or other	Species	Clay pot		CO_2 tent trap			Human landing catches			CDC-light trap	Cattle kraal	Cloth tube	Drum	House search	Male swarm	Modified bucket	Tyre
		KwaZulu-Natal	Mpumalanga	KwaZulu-Natal	Mpumalanga	Limpopo	KwaZulu-Natal	Mpumalanga	Limpopo	Limpopo	KwaZulu-Natal	KwaZulu-Natal	KwaZulu-Natal	KwaZulu-Natal	KwaZulu-Natal	KwaZulu-Natal	
An. gambiae complex	*An. arabiensis*	2766	10	47	2	8		16	3		6	215	155	8	8	30	1199
	An. merus	109	2	1	4	2		39		1		4				2	12
	An. quadriannulatus	2		3		102		2	2	32		1					
An. funestus group	*An. leesoni*	120		9	1	111				45	2						27
	An. parensis	776		8							2	20	36	1		4	317
	An. rivulorum	64		3		25				9	7			2		2	17
	An. rivulorum-like					15				12							
	An. vaneedeni	234	1	8	2	1		2		0	4	7				25	44
Other *Anopheles* species	*An. coustani*	33		25	2	22	2	3		42				1		2	4
	An. demeilloni	19	1	1		31				60							1
	An. gibbinsi					35				106							
	An. listeri					12				49							
	An. longipalpis				1												
	An. maculipalpis	10		11							3					2	
	An. marshallii complex	488		23	1						11	13					110
	An. natalensis																
	An. pharoensis	10		39							7	1					1
	An. pretoriensis	3			3	59				108							
	An. rhodesiensis									3							
	An. rufipes	36	1	10	2	14				29	1	10		1		7	
	An. squamosus	4		27							1			1			
	An. tenebrous	25		39		6				10	1	4				1	2
	An. ziemanni	5		2								1					1

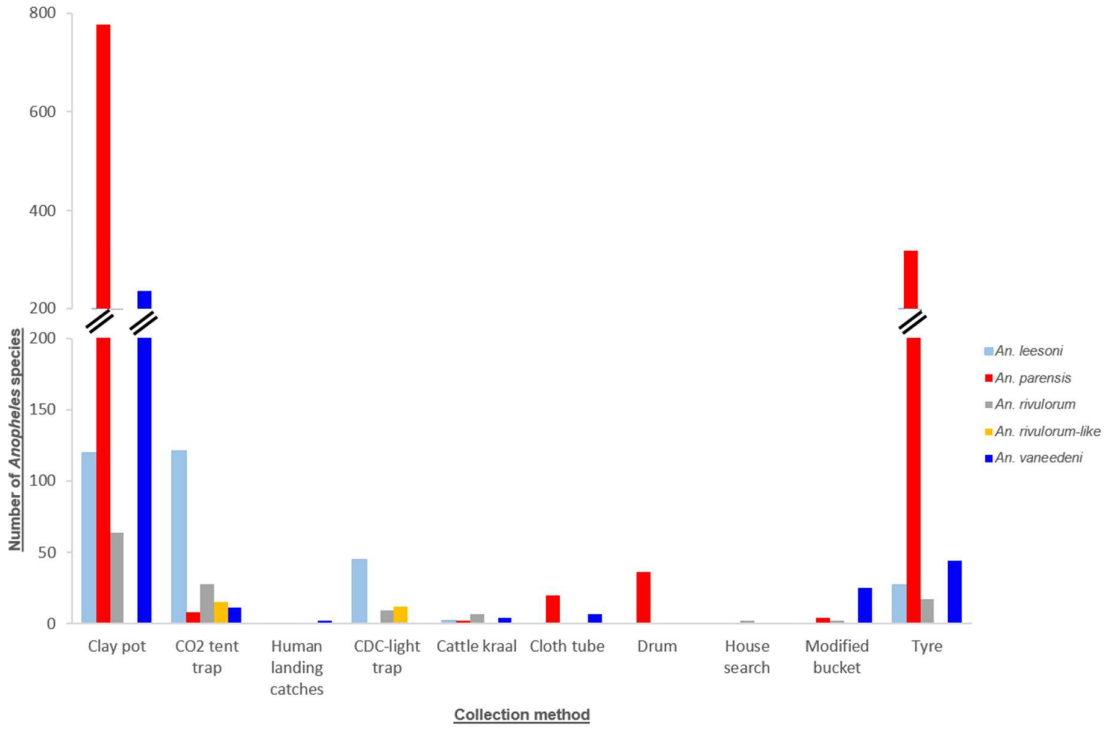

Figure 9. Distribution (in absolute numbers) of *Anopheles funestus* group specimens by sampling method, South Africa, 2021.

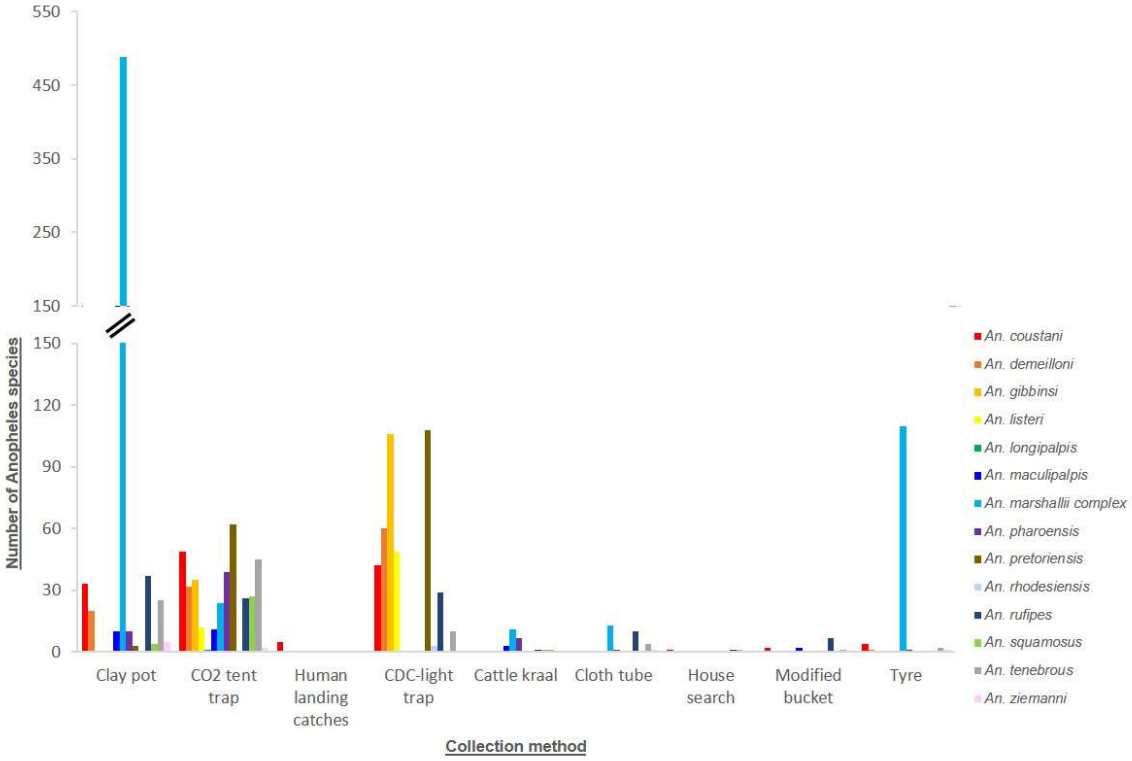

Figure 10. Distribution (in absolute numbers) of miscellaneous *Anopheles* specimens by sampling method, South Africa, 2021.

Discussion

Malaria vector surveillance in 2021 in the KwaZulu-Natal, Mpumalanga and Limpopo provinces of South Africa revealed 15 *Anopheles* species of interest in malaria transmission. The collections included species previously incriminated as vectors in South Africa (*An. arabiensis*, *An. parensis* and *An. vaneedeni*) as well as species incriminated as vectors in other African localities (*An. merus*, *An. leesoni*, *An. rivulorum*, *An. marshallii*, *An. coustani*, *An. demeilloni*, *An. longipalpis*, *An. pharoensis*, *An. pretoriensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni).*[16,17,18,19, 20]

The major vector *An. arabiensis* was the predominant species collected during 2021, accounting for 60% of the specimens collected from KwaZulu-Natal Province. This species was also present in the Mpumalanga and Limpopo Provinces accounting for 14% and 2% of the specimens collected. *Anopheles arabiensis* is currently the major malaria vector in South Africa following the near eradication of *An. funestus* by intensive IRS campaigns over the last two decades.[2, 21] Since *An. arabiensis* females are at least partially inclined to feed and rest outdoors, they are less susceptible to control by IRS.[4,5] This species is therefore the primary vector of residual malaria in South Africa[4], but not the only contributor.

Anopheles merus was collected from all three endemic provinces, with the highest numbers in 2021 coming from Mpumalanga Province, similar to collections in 2019 and 2020. Although *An. merus* has not been definitively implicated in malaria transmission in South Africa to date, its confirmed vector status in other regions such as southern Mozambique (sporozoite rates for *An. merus* in the Boane District being 4.2%)[22] suggests that it is most likely an important secondary malaria vector in South Africa as well. This species is primarily a coastal saltwater breeder, although it has also been collected from fresh-water larval habitats in southern Africa including sites in South Africa.[23]

Anopheles parensis and *An*. *vaneedeni* have been incriminated as secondary malaria vectors in South Africa[3,15], while other members of the *An. funestus* group (*An. rivulorum* and *An. leesoni*) have been implicated as secondary malaria vectors in East Africa. *Anopheles vaneedeni* and *An. leesoni* were collected from all three endemic provinces while *An. parensis* was only detected in KwaZulu-Natal Province during 2021, which was also the case in 2019 and 2020. *Anopheles vaneedeni* likely contributes to residual malaria transmission in South Africa given its tendency to rest outdoors and to feed on humans amongst other vertebrate hosts.[3] *Anopheles parensis* is primarily zoonotic and may rest indoors and outdoors. This species will also occasionally feed on humans[24] and can potentially contribute to residual malaria transmission in South Africa. The major vector *An. funestus s.s.*, the predominant malaria vector species in neighbouring Mozambique and Zimbabwe,

was not detected in South Africa in 2021. This can be attributed to ongoing IRS programmes in the malaria-endemic provinces year on year.

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. longipalpis*, *An. pharoensis*, *An. pretoriensis*, *An. rufipes*, *An. squamosus* and *An. ziemanni* .[16, 17, 18, 19, 20] It is possible that one or more of these species plays a role in residual malaria transmission in South Africa. *Anopheles rufipes*, *An. pretoriensis* and *An. coustani* were present in all three endemic provinces in South Africa in 2021.

Anopheles population densities are expected to fluctuate between seasons. They are generally highest during the summer months, congruent with increased rainfall[4], translating into higher malaria transmission rates during summer and especially late summer. Some species however, especially *An. arabiensis* in northern KwaZulu-Natal Province, were present at comparatively high numbers during the dry winter months. This is likely due to continuous and intensive collections throughout the year in northern KZN by personnel of the Sterile Insect Technique project.[4]

Specimens of the *Anopheles* species directly incriminated as vectors in South Africa - *An. arabiensis*, *An. parensis* and *An. vaneedeni* - were predominantly collected from clay pots. Other potential secondary vectors were predominantly collected from clay pots, tyres, CO_2 tent traps and CDC-light traps. Combinations of these and other collection methods can therefore be used to maximize adult *Anopheles* specimen collections. Owing to substantial variation in the intensity and frequency of collection effort by locality and method, it is not possible to accurately assess which methods are in fact the most productive from this data. The surveillance objectives (key surveillance indicators) by province, district and sentinel site should guide choice of collection methods, as each method has its advantages and disadvantages.

The occurrence of primary and secondary vector species in all three of South Africa's malaria-endemic provinces shows that they remain highly receptive to malaria despite ongoing IRS operations each year. During 2021, the highest number of local malaria cases was recorded in Limpopo Province, from where only 53 (2%) *An. arabiensis* specimen were collected. This suggests that secondary vector species play an important role in ongoing malaria transmission there, which is likely true for the other endemic provinces as well.

Conclusion

Several malaria vector species occur in the north-eastern lowveld regions of South Africa, with their relative abundances remaining comparatively high through the dry winter months in some instances. 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 three of them - *An. arabiensis*, *An. vaneedeni* and *An. parensis* – have previously been implicated in ongoing residual transmission in South Africa (*An. merus* is also a highly likely contributor). The reasons for this are multiple and certainly include outdoor-biting and outdoor-resting components of these species.

Recommendations

- Malaria vector surveillance in South Africa's endemic provinces should be maintained on a weekly to monthly basis, especially during summer and autumn, by provincial entomology teams with the support of partner institutions ((NICD, Wits Research Institute for Malaria (WRIM), University of Pretoria Institute for Sustainable Malaria Control (UP ISMC) and South Africa Medical Research Council (SAMRC)).
- Malaria vector surveillance activities should prioritise the collection of insecticide susceptibility data, especially for populations of major vector species. These data should be collected annually in collaboration with partner institutions. Priority insecticides include deltamethrin, DDT, pirimiphos methyl and clothianidin if possible.
- Other vector bionomics including feeding, resting and breeding behaviours, and assessments of blood source and *Plasmodium* infectivity should continue to be assessed by entomology teams in collaboration with partner institutions.
- Malaria vector surveillance should be conducted biannually (by provincial entomology team personnel) in those districts or municipalities in endemic provinces that are currently malaria free. This provides important information on malaria receptivity and the risk of re-introduction.
- Malaria vector surveillance data should be entered into the provincial DHIS2 systems as they become available. Senior entomology team members with the support of information officers should do this. Partner institutions are strongly encouraged to share their surveillance data with the national and provincial control programmes for inclusion in the DHIS2 databases.
- Annual IRS-based vector control operations should achieve a high rate of coverage (>95%) in areas of active transmission based on incidence data from preceding malaria seasons, and the occurrence of major and secondary vector species.
- IRS activities as conducted by provincial malaria control personnel should ideally be completed before the onset of each malaria season i.e. October – November.
- Consideration should be given to a more targeted or reactive IRS approach in areas where no local cases have been recorded for three or more years. Such an approach can utilise the foci clearing operating procedures.

- Larval source management[25], including the treatment of winter *Anopheles* breeding sites, should be used to enhance the effect of IRS in high incidence areas. Spray team personnel under the guidance of the entomology teams should do this during or immediately after IRS operations, and during the winter months before IRS operations commence.
- Insecticide resistance management practices should be maintained and periodically revised based on vector surveillance information and the market availability/affordability of third generation insecticides. These include products containing one or a combination of the following active ingredients: pyrethroids, pirimiphos methyl and clothianidin.
- Additional vector control methods including dual active ingredient insecticide-treated bed net distribution to migrant communities, community outreach in terms of personal protection methods, housing design and screening, and environmental management (such as drainage of non-utilised water bodies used by mosquitoes for breeding) should be considered pre- and post-malaria elimination at the local level.

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