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Population structure of *Argas arboreus* (Acari: Argasidae) ticks associated with seasonally abandoned mixed heronries, dominated by cattle egrets (*Bubulcus ibis*), in South Africa

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ABSTRACT

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During winter populations of *Argas arboreus* from heronries of the cattle egret, *Bubulcus ibis*, in South Africa are composed of adults, with some predominance of males, and II–IV instar nymphs, in a state of diapause. The period of tick activity, including reproduction and development of eggs, larvae and N_1 nymphs, is synchronized with the nesting and breeding season of their avian hosts. It begins during spring with the return of birds to the heronry, and ceases in autumn through induction of reproductive diapause in engorged females, and behavioural diapause in unfed nymphs and adult ticks. Many ticks showed morphological anomalies and malformations, the study of which could possibly be used for monitoring of environmental pollution.

Keywords: *Argas arboreus*, argasid ticks, birds, *Bubulcus ibis*, heronries

INTRODUCTION

In southern Africa the cattle egret (*Bubulcus ibis*) is a partial migrant, especially in the highveld and the drier northwest, that disperses during winter after breeding activities in spring and summer (Martin 1997). They are highly colonial breeders, often breeding in large numbers in mixed-species heronries (Maclean 1993; Martin 1997; Steyn 1996), and there is usually a high degree of breeding synchrony throughout the heronry (Steyn 1996). Heronries are usually abandoned after the breeding season, but the birds may use the same site for breeding year after year (Brown, Urban & Newman 1982). The nest consists of a platform of sticks or reeds in tree or reedbed (Maclean 1993), and it is not known to what extend nests of a previous season are reused.

The tick *Argas* (*Persicargas*) *arboreus* Kaiser, Hoogstraal & Kohls, 1964 is a common parasite of the cattle egret (*Bubulcus ibis*), as well as other water birds, in their heronries all over the African continent (Khalil, Hoogstraal & Oliver 1980). The feeding of ticks, egg-laying by adult females, and development of the larval and nymphal tick stages coincide with the birds' nesting period during the spring-summer season. During autumn and winter dormant adult ticks and nymphs (both unfed and engorged) are mostly confined to suitable niches in the birds' nesting trees, frequently under loose bark, and in cracks in the trees (Active ticks also inhabit these niches during the day-time in the spring-summer period). The dormant state of the adult ticks is related to reproductive diapause controlled by photoperiod and

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temperature (Khalil 1974; 1976; Khalil & Shanbaky 1976). This life cycle appears to be similar in many regions of the tick's distribution, including Egypt (Kaiser 1966; Guirgis 1971; Hafez, Abdel-Malek & Guirgis 1971; 1972) and South Africa (Belozerov & Kopij 1997).

Argas arboreus overwinters mainly as adults. During the winter in Egypt, which lasts from October through March and during which birds are absent from the heronries, adult ticks represent 70–85 % of the total overwintering tick population, the rest consisting of $N_{2–4}$ instars (Guirgis 1971). In one study in South Africa, adult ticks represented not less than 65 % of the overwintering tick population soon after their hosts begin breeding in the heronry (Belozerov & Kopij 1997). Unfortunately, this study only included the nesting period of the birds, and data were not gathered when the birds were absent from the heronry.

In this article additional data are presented on the population structure of overwintering *A. arboreus* ticks at some South African heronries, dominated by cattle egrets, immediately before and after birds return to the nesting sites.

MATERIALS AND METHODS

The study was carried out in heronries consisting of several bird species, of which cattle egrets were the dominant species and the sacred ibis, *Threskiornis aethiopicus*, additional inhabitants. In some colonies, reed cormorant, *Phalacrocorax africanus* and the African spoonbill, *Platalea alba*, and their nests, were also present. Ticks were collected at heronries within the Free State Province, South Africa, at the localities listed below.

Wolwekop Farm (WF)

This heronry is situated in trees on the retaining wall of an earth dam on the farm Wolwekop (26°40' E; 29°27' S) in the Dewetsdorp district. It is in the same locality where *A. arboreus* (Belozerov & Kopij 1997) and their main hosts, the cattle egret (Kopij 1997) were studied previously. The dominant tree species used for nesting by the birds at this heronry were *Acacia karroo* and *Rhus lancea*.

Soetdoring Nature Reserve (SNR)

A heronry situated at the water-edge of the Krugersdrift Dam (25°57' E; 28°51' S) in the Soetdoring Nature Reserve. The dominant tree species used for nesting were also *A. karroo* and *R. lancea*.

Willem Pretorius Game Reserve (WPGR)

This heronry was situated on a small island in the Allemanskraal Dam (27°09' E; 28°18' S) in the Willem Pretorius Game Reserve. *Eucalyptus* sp. trees and *Rhus* sp. shrubs were mainly used for nesting.

All these heronries have been in existence for many years. Ticks, including nymphs and eggs, were collected from under loose bark and in cracks in trees, and preserved in 70 % ethyl alcohol until they were examined in the laboratory.

In the WF and SNR heronries ticks were collected on 5 and 6 October 2000, before the birds returned. In the WPGR heronry, ticks were collected on 4 November 2000 when the cattle egrets had just returned for nesting (mainly in *Eucalyptus* trees), but sacred ibises had young nestlings in nests which were constructed in *Rhus* sp. shrubs only 30–50 m away. Ticks were collected separately from the *Eucalyptus* trees and *Rhus* shrubs.

RESULTS

The population structure of the tick populations in the various heronries is graphically illustrated in Fig. 1.

WF heronry (Fig. 1A)

The bulk of the tick specimens (76.5 %; 237/310) consisted of adult ticks, with the sex ratio (1:1.2) in favour of males. The remaining ticks were N_2 and $N_{3–4}$ stage nymphs in about equal proportions. No eggs, larvae or 1st instar nymphs were found.

SNR heronry (Fig. 1D)

Adult ticks comprised 79.2 % (251/317) of the overwintering population with the sex ratio (1:1.4) in favour of males. The rest of the population consisted mostly of $N_{3–4}$ stage nymphs (18.0 %), while N_2 nymphs contributed only 2.8 % of the population. Neither larvae nor N_1 nymphs were collected, and only a small batch of about 12 recently laid, viable eggs was found.

WPGR heronry (Fig. 1E)

A total of 399 ticks were collected from the *Eucalyptus* trees that housed cattle egret nests. The adults predominated (71.2 %), whilst the female to male ratio was 1:1.9. About a quarter of the sample consisted of $N_{2–4}$ nymphs, and N_1 nymphs were present. Numerous batches of freshly laid eggs were observed under the bark of the trees.

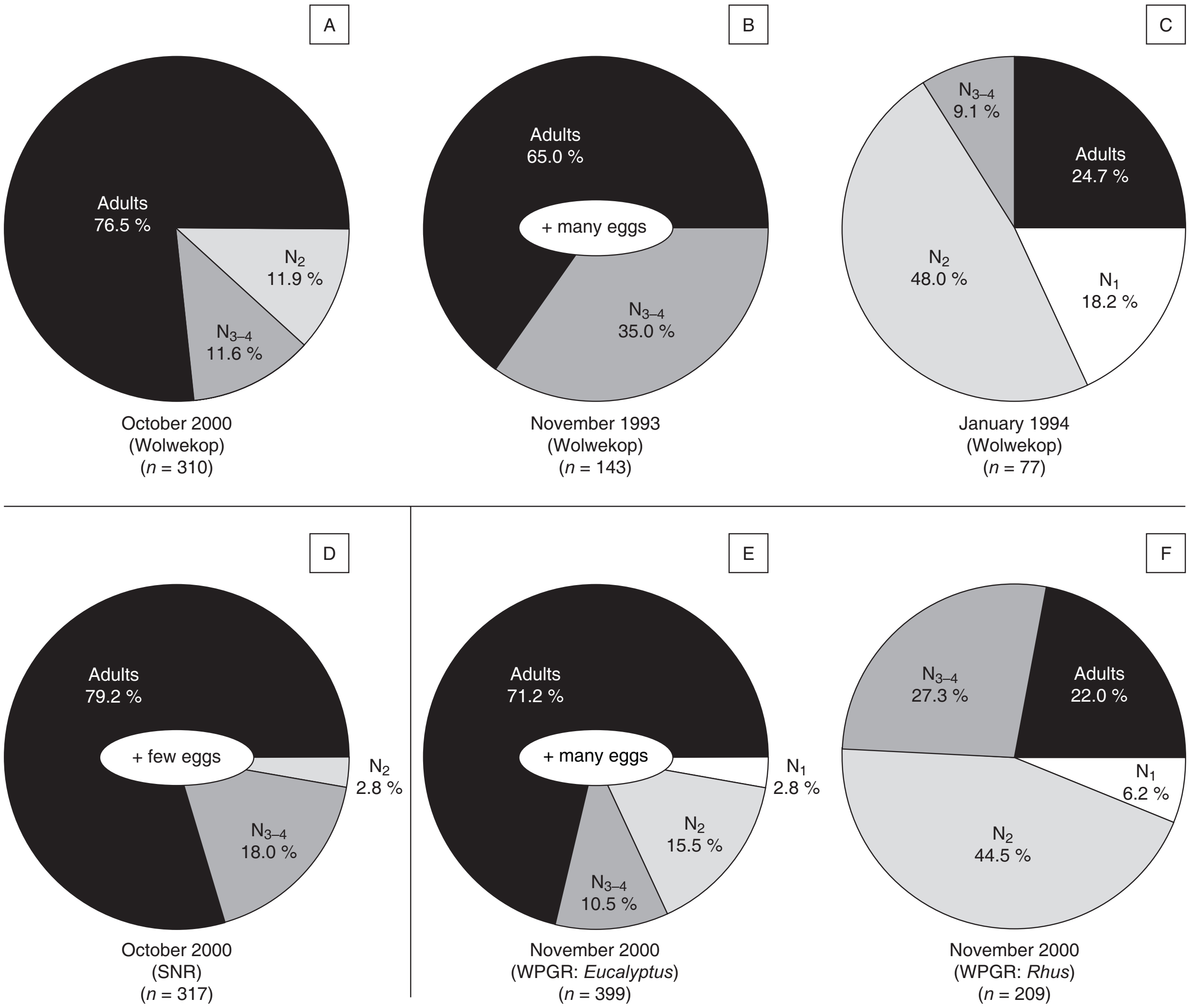

FIG. 1 Population structure of *Argas arboreus* at Wolwekop (A, B, C), Soetdoring Nature Reserve (SNR; D) and Willem Pretorius Game Reserve (WPGR; E, F) heronries, South Africa. Data of figures B and C from Belozerov & Kopij (1997)

The 209 ticks collected from *Rhus* sp. shrubs in which the sacred ibis nests with young nestlings were located were composed of $N_{2–4}$ nymphs (71.8 %), and adult ticks were much less common (Fig. 1F). The sex ratio of adults was close to parity (52 % males and 48 % females). N_1 stage nymphs were present, but no larvae were observed in either of the two samples (Fig. 1E and F).

Abnormalities of *A. arboreus*

Many ticks in all samples had various abnormalities in their external morphology, the most common being damaged, stumpy and shortened legs, as well as body asymmetry and the appearance of spots with changed cuticular structure. The number of ticks with limb and body abnormalities were especially high at WF (29.7 %; 92/310 ticks), while the least malformations were observed in ticks from SNR (7.9 %; 25/317 ticks). At WPGR 16.8 % (67/399) of ticks collected on *Eucalyptus* sp. trees and 20.6 % (43/209) of ticks collected on *Rhus* sp. shrubs had abnormalities.

In the October sample collected at WF before the return of the birds, a progressive increase in malformations was observed from N_1 nymphs (13.5 %) to adult ticks (33.4 %).

In the November sample from WPGR, where birds had already returned to the heronry, the greatest proportion of malformations was evident in the $N_{3–4}$ stage nymphs (21–24 %) with lower proportions in adult ticks (15–17 %) and N2 nymphs (11–18 %).

DISCUSSION

The proportion of adult and $N_{2–4}$ nymphs is similar for the samples from WF (Fig. 1A), SNR (Fig. 1D) as well as the *Eucalyptus* tree sample from WPGR (Fig. 1E). By contrast, the Rhus sample collected only 30–50 m away from, and concurrently with the Eucalyptus tree sample was completely different, with $N_{1–4}$ nymphs dominating the sample (Fig. 1F). Since the *Rhus* sample were collected at a heronry that was in a more advanced breeding cycle phase (nestlings) than the other samples, which were collected from heronries that were in the very early phases of the breeding cycle (i.e. just before or after the birds returned), it is possible that the breeding phase of the birds might have an influence on the ticks life cycle.

An earlier study of the ticks at the WF heronry (Belozerov & Kopij 1997) did show changes in the population composition of the ticks (Fig. 1B, C). Just after the birds' return to the heronry 65.0 % of the tick population consisted of adults, with $N_{3–4}$ nymphs accounting for the balance (Fig. 1B). Many recently laid eggs were also found. Two months later, when most birds had nestlings, $N_{1–4}$ nymphs dominated the sample and adult ticks contributed only 24.7 % to the population (Fig. 1C). It therefore seems likely that the life cycle of *A. arboreus* is indeed closely linked to that of their avian hosts.

The data obtained confirm the strong seasonality of the Argas ticks' life cycle, which is characterized by a definite alternation between active and dormant periods that correspond to the seasonal rhythms in the activities of their hosts. Tick feeding, development and reproduction is synchronized with the nesting and breeding periods of the birds during the spring-summer season both in Egypt (Guirgis 1971; Hafez *et al*. 1971; 1972) and in South Africa (Belozerov & Kopij 1997). The current study also confirms the results of previous studies that adult and $N_{2–4}$ nymphal A. arboreus are the stages that overwinter (Guirgis 1971; Hafez *et al*. 1971; 1972; Belozerov & Kopij 1997). In both southern and northern populations of *A. arboreus*, adult ticks comprise 70–85 % of the overwintering reserve, with $N_{2–4}$ nymphs making up the balance. Eggs, larvae and N_1 nymphs do not overwinter and their appearance and development coincide with the spring-summer period. This synchronization, undoubtedly, is made possible by a photoperiodically-controlled reproductive diapause in adult females (Khalil 1974; 1976). The period of egg-laying, followed by the development of larvae and N1 nymphs, is temporally limited due to the reproductive diapause, and this results in the accumulation of an overwintering reserve of older nymphs and adult ticks.

The data of Guirgis (1971) suggest that behavioural diapause of unfed adults and nymphs are essential for the maintenance of the normal seasonal cycle of *A. arboreus*. This was shown by the behaviour of ticks during the winter of 1966–1967 in Egypt when the seasonal rhythm of birds was disturbed and the ticks retained their dormant state, although the birds did not leave the heronries. This behavioural diapause ensures the dormant state of unfed adult and nymphs, and results in preservation of the population structure in the overwintering population of ticks until their hosts return to the heronries. Returning birds are met by overwintered hungry ticks that are ready to attack their hosts, as soon as the birds begin nesting and breeding. This explains the earlier onset of tick development in places colonized by sacred ibises (Fig. 1F), compared to those colonized at a later stage by cattle egrets (Fig. 1E). The engorged females overwinter in a reproductive diapause state and are activated by increased daylength during spring. Oviposition is initiated at the time their hosts return to the heronry after wintering elsewhere, or even earlier as evidenced by the eggs found before the birds had returned to the SNR heronry. A decrease in the proportion of nymphs in the tick populations during autumn, both in Egypt and South Africa, after birds had left the heronries (Belozerov & Kopij 1997), indicates that engorged nymphs, in contrast to females, do not display an autumnal developmental arrest, but continue to moult. This results in an increased proportion of adults within the overwintering reserve of *A. arboreus*. This latter fact, however, requires verification under experimental conditions.

Our data on the population structure of *A. arboreus* confirm previous conclusions that the life cycle of this parasite of water birds that nest in colonies in Africa is normally univoltine. There are, however, additional options for either biennial development or bivoltine development with seasonal synchronization by means of facultative diapause at the $N_{2–4}$ and adult stages. The combination of the three types of development, with overlapping life cycles of different duration, results in an increased hardiness and stability of local populations of this tick.

Similar patterns in development are also characteristic of argasid ticks in more temperate climates. The duration of the life cycle of the pigeon tick *Argas (Argas) reflexus* Fabr. in Europe varies between 3 and 11 years, but development of generations is well synchronized by means of various seasonal adaptations, which are specific for every post-embryonic stage. The overwintering reserve in this species is therefore more complex, consisting of unfed and engorged larvae, $N_{1–4}$ and adult ticks in a state of diapause (Dautel & Knulle 1997). In the cosmopolitan fowl tick *A. (Persicargas) persicus* Oken the ability to overwinter is present in all stages of its life-cycle, including the egg stage (Galuzo 1957), and this explains the very wide geographic distribution of this tick. Similar adaptations in *Ixodes (Ceratixodes) uriae* White, a circumpolar parasite of colonial sea birds, enable the perfect coordination of its development with the breeding seasons of its hosts under the severe conditions of both the Subarctic (Karpovich 1973; Eveleigh & Threlfall 1974) and Subantarctic regions (Frenot, De Oliveira, Gauthier-Clerc, Deunnf, Bellido & Vernon 2001), in spite of the long duration of its life cycles there (3–7 and 2–4 years respectively). This is possible through overwintering of all postembryonic stages (in unfed state), as well as by an extended egg diapause. Thus, the set of regulatory stages with an ability for diapause is quite vast, but rather variable in ticks parasitizing colonial birds. In cosmopolitan *A. persicus* and circumpolar *I. uriae* they include the egg and all postembryonic stages, in European *A. reflexus* all postembryonic stages, and in African *A. arboreus* only adult ticks and $N_{2–4}$ instars.

The off-host location of *A. arboreus* larvae is unknown. According to Belozerov & Kopij (1997) and Guirgis (1971) very few or no larvae (either unfed or engorged) are found hiding under bark and in its crevices with nymphs and adult ticks. It is much easier to find larval ticks when they are feeding on fledged nestlings of cattle egrets. Some data suggest that engorged larvae can be found in the litter under trees after detachment from nestlings (Guirgis 1971). This requires further investigation.

It would appear that malformations of the nymphs and adults of *A. arboreus* are frequent. Many different forms of teratological abnormalities induced by regeneration and external factors have been described by Buczek (1994) in adult and larval *A. reflexus* and *A. persicus,* and by Campana-Rouget (1959) in nymphs of *Ornithodoros parkeri* and *Ornothodoros turicata*. Investigations conducted recently on ixodid ticks of the genus *Ixodes* (Alekseev & Dubinina 1993; Zharkov, Dubinina, Alekseev & Jensen 2000) have revealed a wide distribution of morphological anomalies (in 10–48 % of ticks in different populations) and their dependence on pollution levels in the environment. The conclusion from these investigations concerning biomonitoring of the environment by investigating morphological anomalies in ticks, can be used for the same purpose in population studies of *A. arboreus*.

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