Teratological cases of the ocular patterns in the South African endemic trapdoor spider genus *Stasimopus* Simon (1892) (Araneae, Mygalomorphae, Stasimopidae)

Shannon Mitchell[1*], Catherine Sole[1*] and Robin Lyle[2]

[1]*Department of Zoology and Entomology, University of Pretoria, Hatfield, Pretoria, South Africa.*

[2] *Agricultural Research Council – Plant Health and Protection, Biosystematics, Roodeplaat, Pretoria, South Africa.*

* Corresponding authors. *E-mail addresses:* shannon.mitchell@up.ac.za (S. Mitchell) and catherine.sole@up.ac.za (C. L. Sole).

Abstract

Teratology is the science that deals with the causes and patterns of deformities, abnormalities and defects in the physical development of animals. Teratological occurrences can be due to genetic or environmental conditions. Ocular teratologies are common in hypogean spiders. This communication reports on the occurrence of ocular teratologies of the South African endemic spider family, Stasimopidae. Various museum collections resulting in 181 spiders were examined for cases of ocular teratologies. Six females and one male were found to display some form of teratology. The species found to exhibit these were, *Stasimopus patersonae*, *S. robertsi*, *S. insculptus peddiensis*, *S. griswoldi*, and three unidentified specimens. The teratologies range from reduced eye size to numerous additional eyes. The exact cause of the teratologies is unknown. They could, however, be linked to embryonic trauma or developmental issues, juvenile injury, or unusual environmental conditions during embryonal development. The spiders all survived to adulthood as in hypogeal spiders, eye sight is not the most relied on sense. Understanding the causes of teratologies is important as it may enable researches to predict the effect of increasing chemical use and global climate change on the embryology of spiders.

Keywords

arachnid, deformity, environmental impacts, hypogean, South Africa, teratology

Introduction

Teratology has long been documented and studied in the field of arachnology (Kaston 1982, Jimenez and Llinas 2002). It is the science that deals with the causes and patterns of deformities, abnormalities and defects in the physical development of animals (Balazuc 1948, Ujhazy *et al.* 2012, Burke *et al.* 2018). Reporting teratological cases is important because they may indicate the effect a particular environmental condition may play during development and may be of general interest (Burke *et al.* 2018).

Ocular teratologies are the most frequently reported deformity of the external features of spiders (Jimenez and Llinas 2002). The documentation of teratological cases of the ocular patterns in the Araneae started with Kaston in 1937 in which he described a spider from the family Amaurobiidae and another from the family Corinnidae both with missing eyes (Kaston 1937). Many other cases have been reported since Kaston (Kaston 1962, 1982, Marer 1972, Savory 1977, Ono and Kudo 1996, Noordijk and Heijerman 2016). It has been noted that the teratology of the eyes of spiders tends to be more common in hypogean spiders, due to a stronger reliance on senses other than vision (Jimenez and Llinas 2002). These types of studies have advanced to experimental phases in which researchers are testing different environmental conditions (e.g. temperature changes, high humidity and different chemicals) and how this influences the development of structural abnormalities. These studies were not only carried out on spiders, for example the giant house spider, *Eratigena atrica* (Temperature), but also on other organisms, such as Japanese horseshoe crabs, *Tachypleus tridentatus* (Chemicals) and the tick, *Hyalomma marginatum marginatum* (Humidity) (Itow 1980, Itow and Sekiguchi 1980, Buczek 2000, Napiórkowska *et al.* 2007, Napiórkowska and Templin 2017, 2018). In multiple studies carried out on the giant house spider, it was found that alternating between high and low temperatures during embryogenesis, causes deformities in the pedipalp, legs and prosoma of spiders, which often leads to fatality.

Spiders typically have eight eyes, the Anterior Median eyes (AME) are known as the ‘principal’ eyes, with the other eyes (Anterior Lateral (ALE), Posterior Median (PME) and Posterior Lateral (PLE)) known as ‘secondary’ eyes (Figure 1). Principal and secondary eyes differ extensively in terms of development, structure and function (Morehouse *et al.* 2017).

This communication serves to report the extent of some ocular teratological occurrences found in the South African spider genus *Stasimopus* Simon (1892), which is endemic to Southern Africa. The genus has recently been placed into its own family, Stasimopidae (Opatova *et al.* 2019). It is a large genus comprising of 47 species (World Spider Catalog 2020). These spiders live in retreats comprising vertical burrows or chambers under rocks or on trees which are lined with silk (Dippenaar-Schoeman 2002). The females lead sedentary lifestyles, only exiting the burrow to capture prey within reach of the burrow entrance (Engelbrecht and Prendini 2011, Satler *et al.* 2013). However, the males are nomadic in nature, spending time wandering to locate females and are the drivers of dispersal.

Methods and Materials

Multiple national and international museum collections (Albany Museum, Grahamstown, South Africa; The National Museum, Bloemfontein, South Africa; Ditsong Museum of Natural History, Pretoria, South Africa; Iziko Museum of Cape Town, South Africa; Museum für Naturkunde, Berlin, Germany; National Collection of Arachnida, Pretoria, South Africa) were examined. A total of 142 females and 70 males examined from 39 different species between the sexes. The examined material yielded six females and one male that display some form of teratology (Table 1).

All the specimens were photographed using Zeiss Axio Zoom V16 with the Axiocam 512 colour and stacked with ZEN 2.3 SP1 (Blue Edition) or a Leica M 165C stereomicroscope attached to Leica camera (DMC-2900). Two different systems were required because the males and some females have a steeper carapace and thus required an imaging system with a greater depth of field. All specimens were photographed on a petri dish of glass beads for ease of adjustment.

An ocular teratology is considered to be a deviation from the normal ocular pattern for the genus. This standard pattern is shown in Figure 1.

Table 1. Specimen information for the *Stasimopus* individuals showing some form of teratology.

Species	Sex	Locality	Accession
Stasimopus patersonae (Hewitt, 1913)	Female	SOUTH AFRICA, Eastern Cape province, Perseverance	Albany Museum (Collector number: 1955)
Stasimopus griswoldi (Engelbrecht and Prendini, 2012)	Female	SOUTH AFRICA, North-West province, Brits, Hartebeespoort dam	Ditsong Museum of Natural History (TMSA-24001)
Stasimopus robertsi (Hewitt, 1910)	Female	SOUTH AFRICA, Gauteng province, Pretoria, Lyttelton junction	Ditsong Museum of Natural History (TMSA -3109-3112)
Stasimopus insculptus peddiensis (Hewitt, 1917)	Female	SOUTH AFRICA, Eastern Cape province, Peddie	Albany Museum (AMGS-84594)
Stasimopus sp.	Female	SOUTH AFRICA, Western Cape province, Kleinwaterval	National Collection of Arachnida (NCA) (NCA 2017/1885)
Stasimopus sp.	Female	SOUTH AFRICA, Northern Cape province, Sandkop	National Collection of Arachnida (NCA) (NCA 2019/643)
Stasimopus sp.	Male	SOUTH AFRICA, Eastern Cape province, Bloemhof farm	National Collection of Arachnida (NCA) (NCA 2019/605)

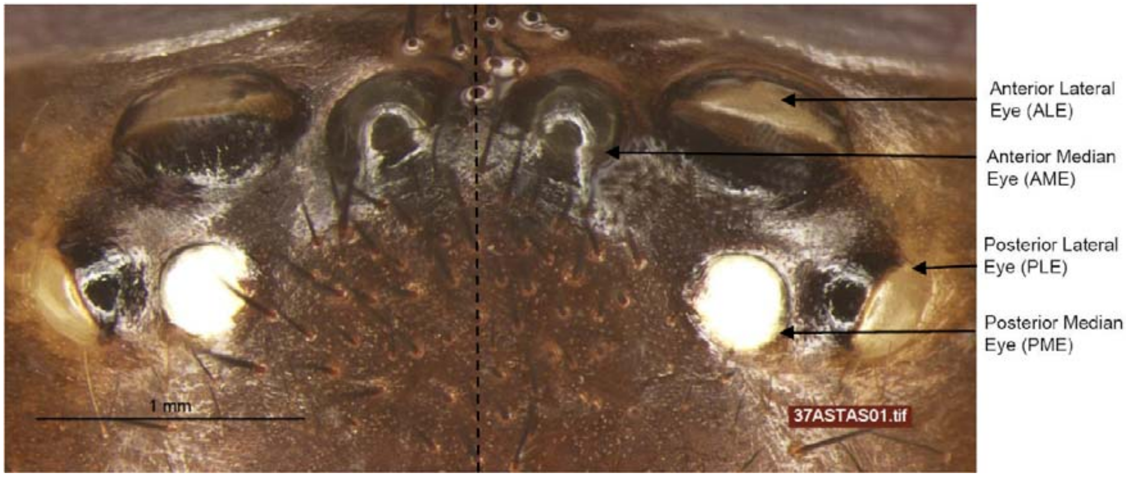

Figure 1: The ocular pattern of a *Stasimopus* female trapdoor spider. This represents the standard number and arrangement of eyes for this genus of spider. Any additional or reduced number indicates a teratology. Any change in the position of the eye in relation to the other eyes is also regarded as an abnormality

Results

The *S. patersonae* female has a growth protruding from the left PME (Figure 2A). The specimen of *S. robertsi* has a teratology of the right PME, which appears to be bifurcating (Figure 2B). *Stasimopus insculptus peddiensis* specimen has a number of deformities (Figure 2C). The right AME is absent entirely. There are six eye-like protrusions to the left of and beneath the right ALE. The right PME is split into two. Both PMEs are bifurcating and the left is partially split. The female of *S. griswoldi* has two smaller, presumably non-functional eyes on either side of the right ALE and one small growth on the outside of the left ALE (Figure 2D). The unidentified female from Kleinwaterval farm (NCA 2017/1885) has what appears to be cuticles for multiple (at least seven) additional eyes, but none of them are completed with lenses (Figure 2E). The additional cuticles to support a lens span from the ALE to the PLE on both sides of the ocular pattern. The other unidentified *Stasimopus* female from Sandkop (NCA 2019/643), has multiple deformities (Figure 2F). The right ALE has two additional eyes to the right. The left ALE has a small additional eye to the left. The right PLE appears to be split into three separate compartments. The unidentified male from Bloemhof farm (NCA 2019/605) has a smaller than usual left AME (Figure 2G).

Figure 2: Ocular teratologies of various specimens of the genus *Stasimopus*. All teratologies are indicated by white arrows. (a). *Stasimopus patersonae* with an additional growth on the left posterior median eye. (b). *Stasimopus robertsi* with an additional growth on the right posterior median eye. (c). *Stasimopus insculptus peddiensis* with a number of deformities. (d). *Stasimopus griswoldi* with three small growths around the anterior lateral eyes. (e). *Stasimopus* species (female, NCA 2017/1885) with many additional growths/eyes surrounding the entire ocular pattern. (f). *Stasimopus* species (female, NCA 2019/643) with

multiple additional eyes and bifurcating eyes. (g). *Stasimopus* species (male, NCA 2019/605) with a smaller right anterior median eye.

Discussion

The exact causes of these deformities are unknown.

The secondary eyes of spiders and scorpions initially develop from a common eye field during embryonic development, this eye field is then split into the separate units (ommatidia) and each unit develops into an eye (Loria and Prendini 2014, Morehouse *et al.* 2017). It is thus plausible that any form of trauma during the splitting of the eye field could cause the deformities seen in Figure 2A, B, C (excluding the AMEs), D, E and F. The development of the separate ommatidia has also been linked to gene expression and an error in this process could lead to the afore mentioned deformations.

Jimenez and Llinas (2002) stated that deformities could be linked to illness or injury during the juvenile stages of a spider's life. This is also recognised in Balazuc (1955) as heteromorphosis which was reported in the ocellus of the spur-throated grasshopper, *Melanoplus* (Orthoptera: Acrididae). It is possible that in the case of additional eyes (Figure 2E and F), a duplication of part of the cephalic region may have occurred during embryonic development (Jimenez and Llinas 2002). The formation of photoreceptors without lenses is believed to be caused by the failure of photoreceptors at recruiting the cuticular lens secreting cells, thus inhibiting the formation of the lens (Morehouse *et al.* 2017). This could be the cause of the deformities seen in Figure 2E. The reasons for the photoreceptor failure are not yet known.

Multiple genes which play a role in general arthropod eye development have been identified in spiders, which implies that the developmental process likely follows a similar pattern (Morehouse *et al.* 2017). From this it can be deduced that loss of the *dac* -gene would lead to the loss of a secondary eye, but not the primary eye. The genetic pathway responsible for primary eye development must still be investigated further to understand what may lead to the loss of AMEs such as in Figure 2C.

It is most likely that these teratologies are the result of environmental conditions during embryonal development. Multiple studies have shown the effects of different temperatures causing various teratologies under laboratory conditions (Napiórkowska *et al.* 2007, Napiórkowska and Templin 2017, 2018). Another possible cause for the deformities reported in this paper is exposure to pesticides during embryonal or post-embryonal development (Holmberg and Kokko 1983, Noordijk and Heijerman 2016). The Karoo region in which the non-identified individuals were collected has been documented to have undergone extensive spraying with the pesticide Deltamethrin for the control of brown locusts (Brown *et al.* 1993, Brown and Kriel 1994, Stewart *et al.* 1994, Price *et al.* 2000). In addition, to Deltamethrin being used in the area, the Northern Cape part of the Karoo underwent many different chemical trails for locust control using Fipronil, Fenvalerate, Tralomethrin, Pyridaphenthion and Alpha-cypermethrin (Price *et al.* 1994, 1996, 2000, Stewart and Napier Bax 1995, Stewart *et al.* 1995, Chambers and de Klerk 1997, Price 2001). These studies stated that the chemicals cause a 'knock-down state', in which the locusts become paralysed for varying amounts of time (Brown *et al.* 1993, Brown and Kriel 1994, Price *et al.* 1996). The locusts either die during the knock-down due to environmental conditions, die after the knock-down due to the pesticide action, or make a full recovery (Brown *et al.* 1993, Brown and Kriel 1994, Price *et al.* 1996). Only two of these studies considered the impact of these trials on non-target organisms, thus the impact this may have had on the spider fauna is unknown (Brown *et al.* 1994, Stewart *et al.* 1994).

For most species of spider, sight is not the main avenue for prey capture. Spiders such as those in this study, live in burrows and are nocturnal. These spiders are more reliant on mechanical and chemical stimuli (Foelix 1996, Jimenez and Llinas 2002). Thus, the impairment of vision would likely not lead to mortality, which may explain how these specimens survived to maturity (Jimenez and Llinas 2002).

More studies are needed to investigate why and how ocular teratologies occur in the Araneae as to better understand the environmental and/or genetic conditions, which underlie this. Long term studies are also suggested which will investigate the impact ocular teratologies have on spider behaviour and survival. It is vital to understand the underlying causes of teratological cases to be able to predict the effects of increasing use of chemicals (pesticides and herbicides) and changing global climate, which may affect the embryology of spiders.

Acknowledgements

We would like to thank the following institutions for loaning the specimens reported on in the communication: Albany Museum, Grahamstown, South Africa; The National Museum, Bloemfontein, South Africa; Ditsong Museum of Natural History, Pretoria, South Africa; Iziko Museum of Cape Town, South Africa; Museum für Naturkunde, Berlin, Germany; National Collection of Arachnida, Pretoria, South Africa. The first author would also like to acknowledge the National Research Foundation for funding (Grant no: 120190). This work is based on the research supported in part by the Karoo BioGaps Project (NRF Grant Number 98864), which was awarded through the Foundational Biodiversity Information Programme (FBIP), a joint initiative of the Department of Science of Technology (DST), the National Research Foundation (NRF) and the South African National Biodiversity Institute (SANBI).

References

Balazuc J. 1948. La Tératologie dês Coléoptères et expériences de transplantation chez *Tenebrio molitor* L. *Mémoires Du Muséum National d'Histoire Naturelle, (Nouvelle série), Paris*, 25: 1–293.

Balazuc J. 1955. La Tératologie des Orthoptéroïdes. A propos de quelques nouveaux faits observationnels et expérimentaux. *Bollettino del Laboratorio di Entomologia Agraria "Filippo Silvestre" di Portici*, 14: 48–64.

Brown HD, Kriel CF. 1994. *Evaluating Deltamethrin UL under operational conditions for the control of the brown locust in South Africa*. Pretoria.

Brown HD, Kriel CF, Butler ET. 1993. *Operational use of Deltamethrin 0.7 ULV formulation by the SADA's locust control organisation and efficacy of RU's is 081-A against African migatory locust, Locusta migratoria migratorioides, in South Africa*. Pretoria.

Brown HD, Price RE, Seesink LD. 1994. *Impact of Deltamethrin on a Dipteran parasite of locusts in South Africa*. Pretoria.

Buczek A. 2000. Experimental teratogeny in the tick *Hyalomma marginatum marginatum* (Acari: Ixodida: Ixodidae): effect of high humidity on embryonic development. *Journal of Medical Entomology* 37 (6): 807–814.

Burke AF, Sole CL, Scholtz CH. 2018. A remarkable teratological case for *Eucymatodera parva* Schenkling, 1908 (Cleridae: Tillinae) from Namibia. *African Entomology* 26 (1): 250–253.

Chambers BQ, de Klerk JC. 1997. *Evaluation of Alpha-Cypermethrin for the control of the brown locust in the karoo, South Africa*. Pretoria.

Dippenaar-Schoeman AS. 2002. *Baboon and Trapdoor Spiders of Southern Africa : An Identification Manual*. Handbook. Pretoria: Plant production research institute. Agricultural Research Council, Pretoria.

Engelbrecht I, Prendini L. 2011. Assessing the taxonomic resolution of southern African trapdoor spiders (Araneae: Ctenizidae; Cyrtaucheniidae; Idiopidae) and implications for their conservation. *Biodiversity and Conservation* 20 (13): 3101–3116.

Foelix RF. 1996. The Biology of Spiders. *In*: *The Biology of Spiders*. Oxford University Press. pp 330.

Holmberg RG, Kokko EG. 1983. A blind *Homolophus biceps* (Arachnida: Opiliones). *Entomological News* 94: 49–52.

Itow T. 1980. Teratogenesis of the horseshoe crab by alpha-lipoic amide (6,8-thioctic amide) in marketed vitamin tablets. *Journal of Nutritional Science and Vitaminology* 26: 237–245.

Itow T, Sekiguchi K. 1980. Morphogenic movement and experimentally induced decrease in number of embryonic segments in the Japanese horseshoe crab, *Tachypleus tridentatus*. *Biological Bulliten* 158: 324–338.

Jimenez ML, Llinas J. 2002. Revision of ocular anomalies in epigean spiders (Arachnida:Araneae) with notes on four new records. *Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Zoología* 73 (2): 241–250.

Kaston BJ. 1937. Structural anomalies in spiders. *Bulletin of the Brooklyn Entomological Society* 32: 104.

Kaston BJ. 1962. Ocular anomalies in spiders. *Bulletin of the Brooklyn Entomological Society* 57: 17–21.

Kaston BJ. 1982. Additional ocular anomalies in spiders. *Journal of Arachnology* 10 (281).

Loria SF, Prendini L. 2014. Homology of the lateral eyes of Scorpiones: A six-ocellus model. *PLoS ONE* 9 (12): 1–30.

Marer PJ. 1972. An eye deformity in a tarantula spider, *Aphonopelma reversum*. *Pan-Pacific Entomology* 48: 221–225.

Morehouse NI, Buschbeck EK, Zurek DB, Steck M, Porter ML. 2017. Molecular evolution of spider vision: New opportunities, familiar players. *Biological Bulletin* 233 (1): 21–38.

Napiórkowska T, Jacuński L, Templin J. 2007. Epimorphosis and repair processes of schistomelic pedipalps and walking appendages in *Tegenaria atrica* (Araneae, Agelenidae). *Biologia, Bratislava* 62 (6): 756–762.

Napiórkowska T, Templin J. 2017. Teratological changes on the prosoma of *Eratigena atrica* spiders caused by alternating temperatures. *Invertebrate Survival Journal* 14: 480–487.

Napiórkowska T, Templin J. 2018. Heterosymely and accompanying anomalies in the spider *Eratigena atrica* (C .L. Kock, 1843) (Araneae: Agelenidae). *Annales Zoologici* 68 (4): 909–914.

Noordijk J, Heijerman T. 2016. A rare teratology in the harvestman *Lophopilio palpinalis* (Opiliones: Phalangiidae). *Arachnology* 17 (2): 100–102.

Ono H, Kudo Y. 1996. The Ocular Anomaly in a Ground Spider (Araneae: Gnaphosidae) from Japan. *Acta Arachnologica* 45 (1): 73–75.

Opatova V, Hamilton CA, Hedin M, De Oca LM, Král J, Bond JE. 2019. Phylogenetic Systematics and Evolution of the Spider Infraorder Mygalomorphae Using Genomic Scale Data. *Systematic Biology* syz064.

Price RE. 2001. *Efficacy of Alpha-cypermethrin (Fastac) against brown locust nymphal bands under cool climatic conditions in the Karoo, South Africa*.

Pretoria.

Price RE, Brown HD, Mitchell JD, Coetzee KE. 2000. *Efficacy of Fipronil in barrier treatments for the control of nymphal bands of the brown locust*. Pretoria.

Price RE, Butler ET, Brown HD. 1994. *Efficacy of Fipronil against nymphal bands of the brown locust in the karoo, South Africa*. Pretoria.

Price RE, Butler ET, du Preez I. 1996. *Field trials of Filpronil UL against brown locust nymphal bands in the karoo, South Africa*. Pretoria.

Satler JD, Carstens BC, Hedin M. 2013. Multilocus Species Delimitation in a Complex of Morphologically Conserved Trapdoor Spiders (Mygalomorphae, Antrodiaetidae, *Aliatypus*). *Systematic Biology* 62 (6): 805–823.

Savory T. 1977. Ontogeny. *In*: *Arachnida*. London: Academic Press Inc. pp 49–59.

Sonnini CS, Latreille PA. 1802. Histoire Naturelle des Reptiles. *Librairie Encycopédique de Roret*, 4 volumes: xxii, 280, 332, 335; 4.

Stewart DAB, Butler ET, du Preez I. 1995. *Efficacy of ISOO3N and IS044B against the brown locust in the karoo, South Africa*. Pretoria.

Stewart DAB, Napier Bax P. 1995. *Efficacy of Fenvalerate against the brown locust Locustana pardalina in the karoo, South Africa*. Pretoria.

Stewart DAB, Price RE, Butler ET. 1994. *Environmental impact of Deltamethrin on non-target organisms in the Karoo*. Pretoria.

Ujhazy E, Mach M, Navarova J, Brucknerova I, Bubovicky M. 2012. Teratology- past, present and future. *Interdisciplinary Toxicology* 5: 163–168.

World Spider Catalog, 2020. World Spider Catalog Version 21.0. *Natural History Museum Bern*. Available at http://wsc.nmbe.ch [accessed 1 October 2020].