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Jana Beckert, Hartmut Greven & Klaus Lunau

Summary: Males of the 'glowspot' cockroaches of the genus *Lucihormetica* are characterized by two symmetrically arranged spots on the pronotum, which (i) are of whitish yellow to red color, depending on the amount of carotenoids in the diet, and (ii) show a strong autofluorescence when exposed to UV radiation. Recently, it was suggested to consider the carotenoid-based coloration of the spots as condition-dependent trait informing the potential mate and/or rival about the quality of the respective male. In the literature the UV-fluorescence of the cuticle was erroneously considered to be bioluminescence. We herein demonstrate a close relationship between coloration caused by carotenoids and autofluorescence of the spots in *L. verrucosa*. The redder the spots, i.e. the higher the carotenoid content of the fat body, the less the intensity of their autofluorescence and UV-reflectance. In addition, we provide some evidence that the 'substance' responsible for the autofluorescence is largely localized in the cuticle covering the spots.

Keywords: Glowspot cockroach, carotenoids, autofluorescence, UV-reflection

Zusammenfassung: Männchen von ‚Leuchtschaben' (Gattung *Lucihormetica*) zeichnen sich durch zwei symmetrisch angeordnete Flecken auf ihrem Pronotum aus, die (1) in Abhängigkeit vom Carotinoidgehalt der aufgenommenen Nahrung weißgelb bis rot gefärbt sein können und (2) im UV-Licht fluoreszieren. Kürzlich ist vorgeschlagen worden, die carotinoidabhängige Färbung der Flecken als konditionsabhängiges Merkmal anzusehen, das den potenziellen Paarungspartner und/oder Rivalen über die Qualität seines Trägers informiert. Die Autofluoreszenz der Cuticula ist in der Literatur irrtümlich als Biolumineszenz gedeutet worden. Wir zeigen hier an *L. verrucosa* einen engen Zusammenhang zwischen der durch den Carotinoidgehalt verursachten Färbung der Flecken und ihrer Autofluoreszenz. Je intensiver rot die Flecken sind, d.h. je höher der Carotinoidgehalt des Fettköpers ist, desto weniger intensiv waren die Autofluoreszenz und UV-Reflexion. Zudem gibt es Hinweise, dass die Substanz, die für die Autofluoreszenz verantwortlich ist, weitgehend in der die Flecken bedeckenden Cuticula liegt.

Schlüsselwörter: Leuchtschaben, Carotinoide, Autofluoreszenz, UV-reflexion

1. Introduction

Glowspot cockroaches of the genus *Lucihormetica* are widely distributed in South American forests (Brazil, Columbia, Venezuela etc.) and highly sexually dimorphic (e.g. Zompro & Fritzsche 1999). Contrary to females, adult males have two symme-

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1. Introduction

Glowspot cockroaches of the genus *Lucihormetica* are widely distributed in South American forests (Brazil, Columbia, Venezuela etc.) and highly sexually dimorphic (e.g. Zompro & Fritzsche 1999). Contrary to females, adult males have two symmetrically arranged white yellow to red spots on the pronotum, which show a strong fluorescence when dead or live specimens were exposed to UV-light. The autofluorescence property of the spot-cuticle was erroneously interpreted as bioluminescence (VRŠANSKÝ et al. 2012; VRŠANSKÝ & DUSAN 2013). However, as is commonly understood, UV-fluorescence is not bioluminescence (see MERRITT 2013).

GREVEN & ZWANZIG (2013) showed that the spots are covered by a transparent cuticle that is underlain by the thin epidermis and an aggregation of fat body cells that obviously accumulate carotenoid pigments. The authors did not find any evidence for typical luminescent structures or bioluminescent bacteria.

Carotenoids absorb light of wavelengths between 400 and 550 nm (FRANK 2008) and fulfil several important physiological functions. They have antioxidant properties that protect cells and tissues (including the immune system) from oxidative damage by capturing and destroying harmful free radicals (summarized in MCGRAW & ARDIA 2003; BLOUNT & MCGRAW 2008). Usually, animals obtain carotenoids from a vegetarian diet and many employ conspicuous carotenoid-based color signals, whose intensity depends on the diet. Therefore, the color of the spots in males of *L. verrucosa* was suggested to be a condition-dependent trait containing information about the quality, i.e. health status, for potential mates and/or potential rivals (GREVEN & ZWANZIG 2013), provided they can perceive the signals.

In the present note we report an unexpected result we obtained as we manipulated the color of the spots by different diets and then measured their absorbent properties under different light conditions (daylight and UV-light). It was suggested that the red spots would be the most noticeable signals for conspecifics under every conceivable light condition.

2. Material and methods

2.1. Feeding of experimental animals

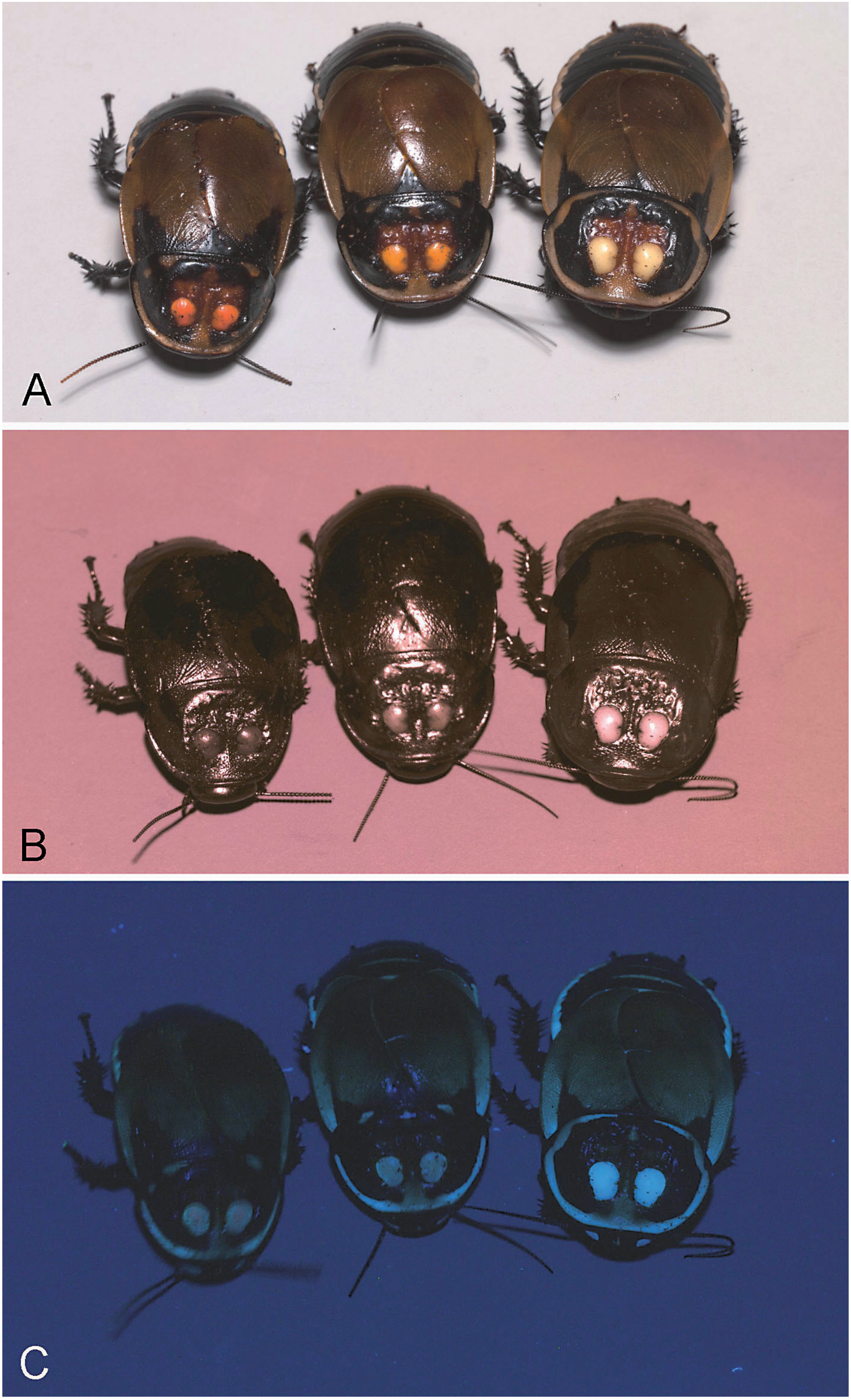
Experimental specimens of *Lucihormetica verrucosa* were from a breeding stock held in the institute. Small groups of cockroaches separated by sex were kept at approx. 20 °C in several small plastic boxes with coconut fibres as substrate. They received either (1) a mixture of a carotene-rich food (carrots, food flakes for tropical fish (sera Vipan, Fa. Sera GmbH, Heinsberg; Tetra Rubin, Fa. Tetra GmbH, Melle)), (2) food with a lower carotene content (yellow peppers, food flakes for fish (MultiFit XL, Fa. MultiFit Tiernahrungs GmbH, Krefeld)), or (3) a diet low in carotenoid content (oat flakes).

2.2. Spectrophotometry

The spectral reflectance of two intensely 'red' colored spots of a male given the carotenoid-rich diet and of two 'white' spots of a male fed only oat flakes were measured with the spectrophotometer USB4000 (Oceans Optics Inc., Dunedin, Florida) across a wavelength range of 300-700 nm using the program SpectraSuits (Oceans Optics Inc.). The bright standard was pressed barium sulphate, the dark standard was a black film container. As the spots are

Fig. 1: Males of *Lucihormetica verrucosa* after feeding with a diet rich (left) and poor (middle) in carotenoids and lacking carotenoids (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter. Photos: C. VERHOEVEN

Abb. 1: *Lucihormetica verrucosa*-Männchen nach Fütterung mit carotinoid-reicher (links), carotenoid-armer (Mitte) und carotinoid-freier Nahrung. **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter. Fotos: C. VERHOEVEN


A
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slightly raised and the reflection depends on the angle and orientation of the surface receiving the irradiation, the sensor head was positioned above the spots at different angles. Mean values were calculated from 8 to 9 measurements per male.

2.3. Photography

Photos were taken from (1) freshly killed specimens and (2) from pronota, where the tissue was removed by trypsin, with a Lumix GH-1 and an Ultra-Achromatic-Takumar 1:4.5/85 objective and various filters (Fa. Baader, Munich) depending on the type of the photographs: day light (25 Watt, Tageslichtlampen24.de) was used for standard photos (UV/IR-Cut-Filter, 400-700 nm), an ultraviolet torch (Fa. MTE, Singapur) was used for UV (U-Filter; 320-380 nm with a maximum at 350 nm) and fluorescence photos (UV/IR-Cut-Filter).

3. Results

Under the above mentioned diet conditions, the pronotum-spots of the males fed with the carotenoid-rich food were colored bright red, whereas the spots of the males fed only with oat flakes remained pale. Males consuming a diet less rich in carotenoids generally had an intermediate color (Fig. 1 A). Under UV light the white-yellow spots reflect more UV light, while those of the red cockroach absorb this light more strongly (Fig. 1 B). Photos taken under UV light with a UV/IR-Cut-Filter clearly revealed that the white-yellow spots showed stronger blue fluorescence than the red spots (Fig. 1 C). Furthermore, white yellow spots exhibited a clear UV-reflectance by emitting light in the shortwave range, whereas red spots absorb light in this range of wavelength (Fig. 2).

By removing the soft tissue, i.e. epidermis and fat body underneath the cuticle, with trypsin, the reflectance properties of the spots were changed (Figs 3, 4). Compared with the freshly killed intact specimen (Fig. 3, left side) the cuticle of the previously red spots became transparent, the fluorescence was largely retained and the UV-reflectance seemed to increase a little (Fig. 3, right side). In previously white spots, UV-reflectance and especially fluorescence appeared to decrease to some extent (Fig. 4).

4. Discussion

Firstly, our feeding experiments confirm previous observations made mainly by breeders (e.g. Fritzsche 2013), showing that the coloration of the pronotum spots of *Lucihormeti-*

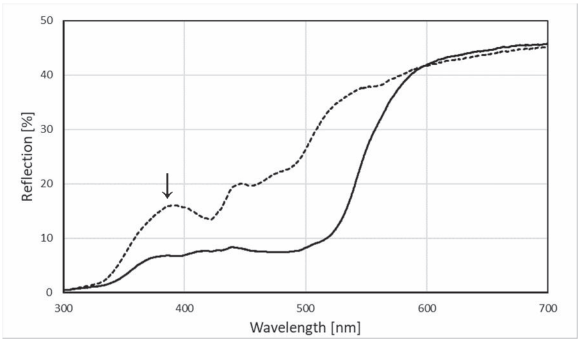

Fig. 2: Spectral reflectance curves of red (black curve) and white-yellow (dotted curve) spots. Note the peak (arrow).

Abb. 2: Spektrale Reflexionskurven von roten (schwarze Kurve) und weißgelben (gepunktete Kurve) Flecken.. Man beachte die erhöhte Reflexion (Pfeil).

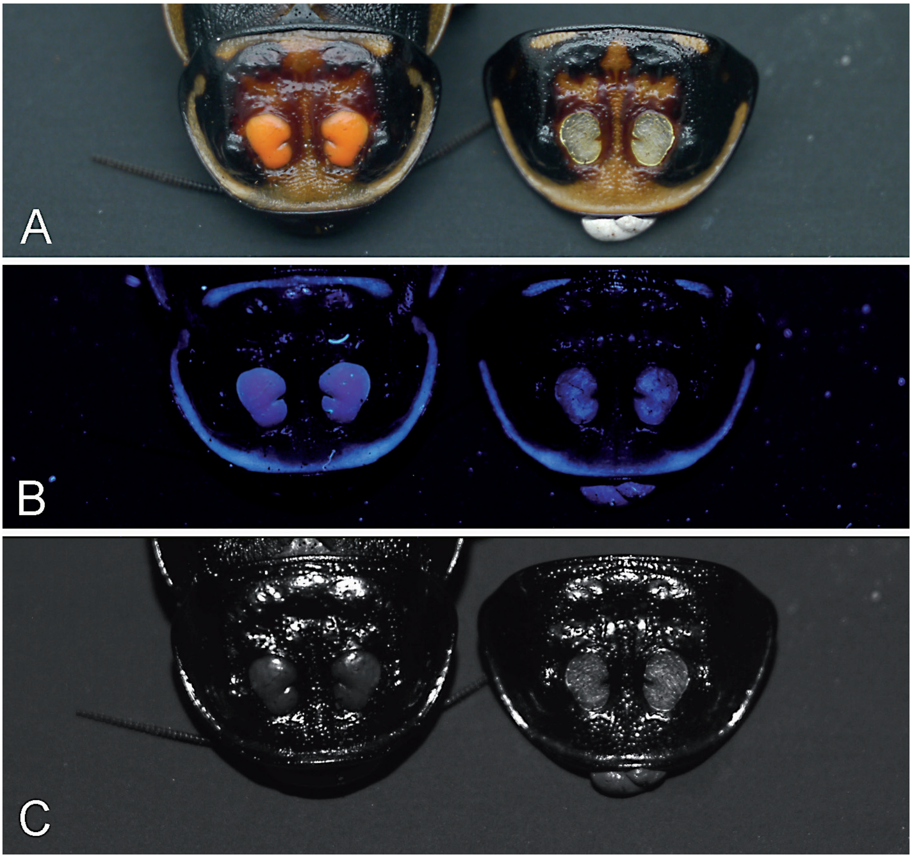

Fig. 3: Red spots of a freshly killed male of *Lucihormetica verrucosa* (left) and of the pronotum deprived of soft tissue (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter.
Abb. 3: Rote Flecken eines frisch getöteten *Lucihormetica verrucosa*-Männchens (links) und eines Pronotums ohne Weichgewebe (rechts). **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter.

ca spp. is caused by a carotenoid containing diet. The intensity of the red coloration depends on the amount of carotenoids fed to the males. Obviously, these carotenoids accumulate in the fat body and are visible through the transparent cuticle covering the spots (Greven & Zwanzig 2013).
Secondly, the photos taken with various filter combinations show the already known autofluorescence of the spots, whose intensity clearly depends on the diet.
Thirdly, spectral reflectance curves of red spots indirectly prove the presence of carotenoids, as characterized by their absorbing properties (see Frank et al. 2008). The peak reflectance of red spots is shifted into the red range of wavelength of approx. 500 nm, while the spots of cockroaches fed with a carotenoid poor diet reflect light of shorter wavelengths, resulting in a whitish yellow appearance. The reflectance curves of the white spots show also a peak in the UV-range (around 380 nm) indicating UV-reflectance.
Photoluminescence, i.e. light emission as a result of the absorption of light or strictly

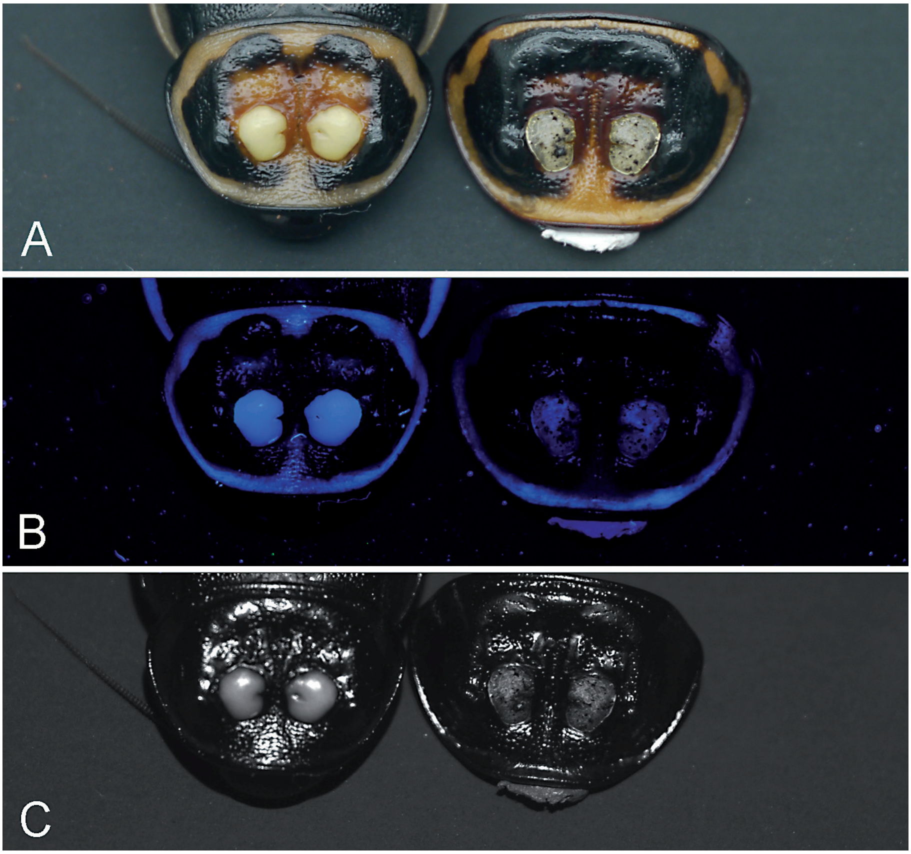

Fig. 4: White yellow spots of a freshly killed male of *Lucihormetica verrucosa* (left) and of the pronotum deprived of soft tissue (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter.
Abb.4: Weißgelbe Flecken eines frisch getöteten *Lucihormetica verrucosa*-Männchens (links) und eines Pronotums ohne Weichgewebe (rechts). **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter.

speaking fluorescence caused by UV light is widespread in arthropods, e.g. in the body cuticle and in specific cuticular markings (e.g., various arthropods: LAWRENCE 1954; isopods: ZIMMER et al. 2002; GIURGINCA et al. 2015; harvestmen: ACOSTA 1983, spiders: ANDREWS et al. 2007; scorpions: LAWRENCE 1954; KLOOCK 2005; the millipede *Paraspilobolus lucifugus*: MEYER-ROCHOW, pers.com., etc.). This endogenous fluorescence is often related to the protein component of the cuticle (ZILL et al. 2000) of which one of the most widespread is resilin (e.g. NEFF et al. 2000; WIESENBORN 2001; MICHELS & GORB 2012). But other fluorescent compounds such as the alkaloid β-carboline and 7-hydroxy-4-methylcoumarin have been identified, e.g. in the epicuticle of scorpions (STACHEL et al., 1999; FROST et al. 2001). Yet, there is still no empirical evidence that neither conspecifics of *L. verrucosa* nor any other organisms respond to the spot fluorescence. Some authors believe that autofluorescence is an intrinsic property of arthropod exoskeletons without any functions (STACHEL et al. 1999; MAZEL

2007). It has, however, been known that cockroaches representing the genera *Periplaneta* and *Blatta* possess UV and green receptors in their eyes (Mote & Goldsmith 1970; Mazokhin-Porshnyakov & Cherkasov 1985).

Autofluorescence and UV-reflectance of the spots covering cuticle of *L. verrucosa* are obscured by the carotenoid content of the underlying fat body. If this carotenoid-rich tissue is removed, transparency of the cuticle is evident, but the cuticle retains to some extent both, the UV-reflectance and the autofluorescence. We do not want to overestimate the minor differences in UV-reflectance between the previously red and white spots, which are probably due to the technique used. However, the differences between the autofluorescence of white spots with and without the underlying tissue are obvious. Currently we cannot exclude an indirect or direct contribution of the underlying tissue to the autofluorescence and UV-reflectance properties.

Apart from the fact that an accumulation of carotenoids is per se advantageous for *L. verrucosa* males and any other animal considering the physiological importance of these pigments (see literature cited above), the suggestion that they may be used for intraspecific communication appears plausible. It is undisputed that the spots are a clearly visual carotenoid-based signal, which differ in their color intensity depending on the condition of the males. However, this signal can be detected only if conspecifics have the appropriate receptors to do this.

Nothing is known about the visual capacity of *Lucihormetica* spp.. However, retinula cells of the likewise nocturnal cockroach *Periplaneta americana* are highly adapted to low light levels (e.g. Heimonen et al. 2006) and have sensitivity peaks in the green (approx. 507 nm) and UV (approx. 365 nm) range of wavelengths (Mote & Goldsmith 1970; see also *Blatta germanica,* Koehler et al. 1987). *Lucihormetica* spp. seem to be largely nocturnal (see Zompro & Fritzsche 1999; Dittrich et al. 2015). We can therefore assume *Lucihormetica* spp. to have a similar visual system like *P. americana* and *B. germanica.* Since cockroaches appear to have no red-sensitive type of photoreceptor (Mote & Goldsmith 1970; Koehler et al. 1987), the pronotum-spots of males appear, contrary to expectation, less conspicuous if they are red than if they are whitish. If *Lucihormetica* spp. had the same photoreceptor equipment as other cockroach species, they would be able to distinguish between well fed, healthy 'red' males and less well-fed, less healthy 'white' males. It is remarkable, that the perceptible signals would not come from the 'most attractive', reddest males. Regarding the putative superiority of 'red' males, behavioral studies on male-male interactions did not yield any clear results (unpublished), but unpublished data show a significant correlation between the green component of the color of the spots and the attractiveness of the males for females. This fits the known photoreceptor sensitivity in the compound eye of the cockroaches. Further investigations and experiments should be carried out for a better understanding of the visual system of the glow-spot cockroaches and to determine the functional significance of the spots more precisely. It is also possible, that different (or additional) photoreceptor cells have developed in *Lucihormetica* spp. from those present in other genera of cockroaches, e.g. *Periplaneta.* The evolution of photoreceptors is, in most cases, overarching to include all genera of a family, but e.g. in some species of bees additional receptors have also been developed (Briscoe & Chittka 2001).

Acknowledgement

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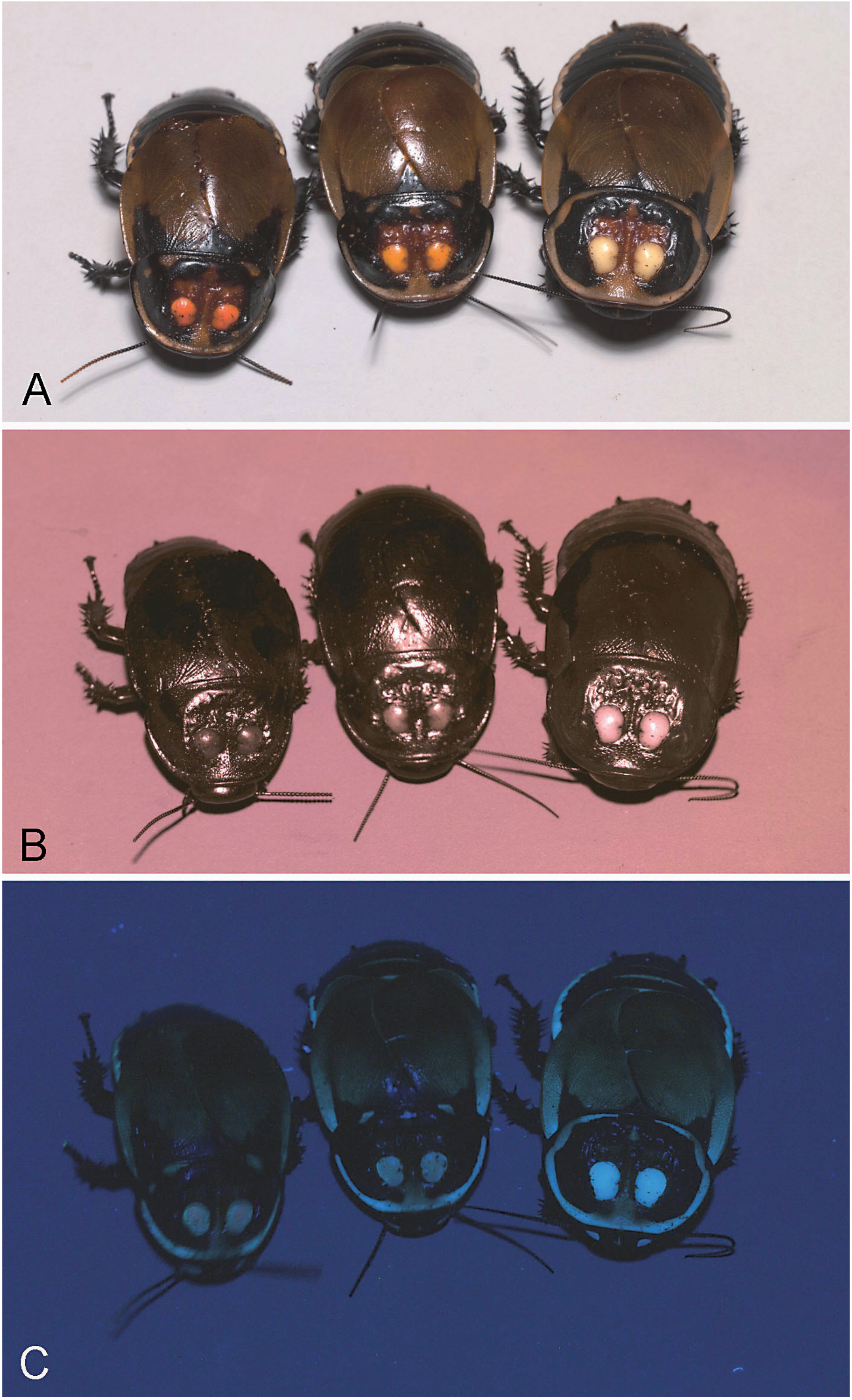
2.2. Spectrophotometry

The spectral reflectance of two intensely 'red' colored spots of a male given the carotenoid-rich diet and of two 'white' spots of a male fed only oat flakes were measured with the spectrophotometer USB4000 (Oceans Optics Inc., Dunedin, Florida) across a wavelength range of 300-700 nm using the program SpectraSuits (Oceans Optics Inc.). The bright standard was pressed barium sulphate, the dark standard was a black film container. As the spots are

Fig. 1: Males of *Lucihormetica verrucosa* after feeding with a diet rich (left) and poor (middle) in carotenoids and lacking carotenoids (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter. Photos: C. VERHOEVEN

Abb. 1: *Lucihormetica verrucosa*-Männchen nach Fütterung mit carotinoid-reicher (links), carotenoid-armer (Mitte) und carotinoid-freier Nahrung. **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter. Fotos: C. VERHOEVEN


A
B
C

slightly raised and the reflection depends on the angle and orientation of the surface receiving the irradiation, the sensor head was positioned above the spots at different angles. Mean values were calculated from 8 to 9 measurements per male.

2.3. Photography

Photos were taken from (1) freshly killed specimens and (2) from pronota, where the tissue was removed by trypsin, with a Lumix GH-1 and an Ultra-Achromatic-Takumar 1:4.5/85 objective and various filters (Fa. Baader, Munich) depending on the type of the photographs: day light (25 Watt, Tageslichtlampen24.de) was used for standard photos (UV/IR-Cut-Filter, 400-700 nm), an ultraviolet torch (Fa. MTE, Singapur) was used for UV (U-Filter; 320-380 nm with a maximum at 350 nm) and fluorescence photos (UV/IR-Cut-Filter).

3. Results

Under the above mentioned diet conditions, the pronotum-spots of the males fed with the carotenoid-rich food were colored bright red, whereas the spots of the males fed only with oat flakes remained pale. Males consuming a diet less rich in carotenoids generally had an intermediate color (Fig. 1 A). Under UV light the white-yellow spots reflect more UV light, while those of the red cockroach absorb this light more strongly (Fig. 1 B). Photos taken under UV light with a UV/IR-Cut-Filter clearly revealed that the white-yellow spots showed stronger blue fluorescence than the red spots (Fig. 1 C). Furthermore, white yellow spots exhibited a clear UV-reflectance by emitting light in the shortwave range, whereas red spots absorb light in this range of wavelength (Fig. 2).

By removing the soft tissue, i.e. epidermis and fat body underneath the cuticle, with trypsin, the reflectance properties of the spots were changed (Figs 3, 4). Compared with the freshly killed intact specimen (Fig. 3, left side) the cuticle of the previously red spots became transparent, the fluorescence was largely retained and the UV-reflectance seemed to increase a little (Fig. 3, right side). In previously white spots, UV-reflectance and especially fluorescence appeared to decrease to some extent (Fig. 4).

4. Discussion

Firstly, our feeding experiments confirm previous observations made mainly by breeders (e.g. Fritzsche 2013), showing that the coloration of the pronotum spots of *Lucihormeti-*

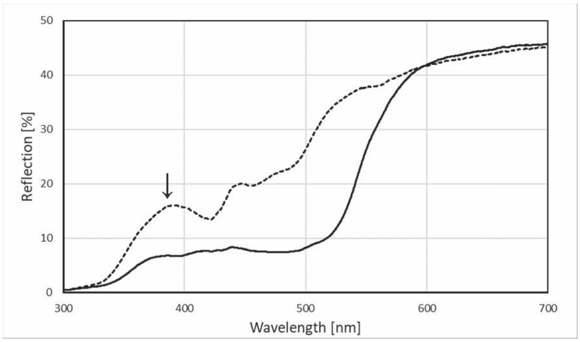


Fig. 2: Spectral reflectance curves of red (black curve) and white-yellow (dotted curve) spots. Note the peak (arrow).

Abb. 2: Spektrale Reflexionskurven von roten (schwarze Kurve) und weißgelben (gepunktete Kurve) Flecken.. Man beachte die erhöhte Reflexion (Pfeil).

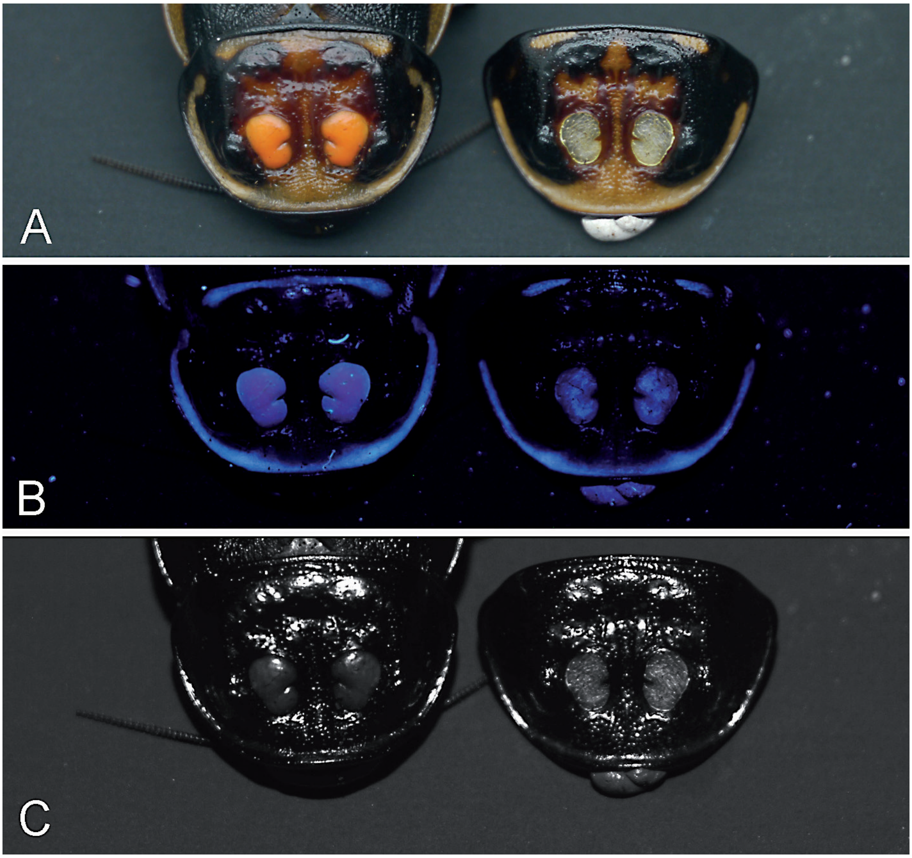


Fig. 3: Red spots of a freshly killed male of *Lucihormetica verrucosa* (left) and of the pronotum deprived of soft tissue (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter.
Abb. 3: Rote Flecken eines frisch getöteten *Lucihormetica verrucosa*-Männchens (links) und eines Pronotums ohne Weichgewebe (rechts). **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter.

ca spp. is caused by a carotenoid containing diet. The intensity of the red coloration depends on the amount of carotenoids fed to the males. Obviously, these carotenoids accumulate in the fat body and are visible through the transparent cuticle covering the spots (Greven & Zwanzig 2013).
Secondly, the photos taken with various filter combinations show the already known autofluorescence of the spots, whose intensity clearly depends on the diet.
Thirdly, spectral reflectance curves of red spots indirectly prove the presence of carotenoids, as characterized by their absorbing properties (see Frank et al. 2008). The peak reflectance of red spots is shifted into the red range of wavelength of approx. 500 nm, while the spots of cockroaches fed with a carotenoid poor diet reflect light of shorter wavelengths, resulting in a whitish yellow appearance. The reflectance curves of the white spots show also a peak in the UV-range (around 380 nm) indicating UV-reflectance.
Photoluminescence, i.e. light emission as a result of the absorption of light or strictly

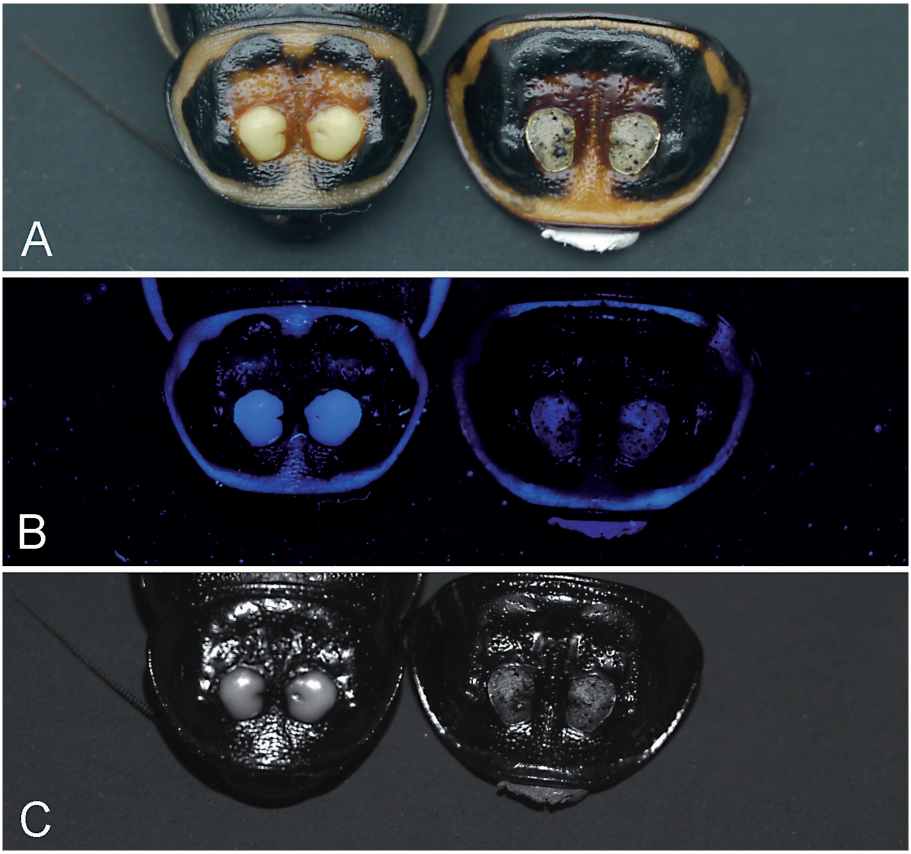


Fig. 4: White yellow spots of a freshly killed male of *Lucihormetica verrucosa* (left) and of the pronotum deprived of soft tissue (right). **A** Standard: daylight lamp; UV/IR-Cut-Filter. **B** UV: UV torch; U-Filter. **C** Fluorescence: UV torch; UV/IR-Cut-Filter.

Abb.4: Weißgelbe Flecken eines frisch getöteten *Lucihormetica verrucosa*-Männchens (links) und eines Pronotums ohne Weichgewebe (rechts). **A** Standard: Tageslichtlampe; Filter: UV/IR-Cut. **B** UV: UV-Taschenlampe; U-Filter. **C** Fluoreszenz: UV-Taschenlampe; UV/IR-Cut-Filter.

speaking fluorescence caused by UV light is widespread in arthropods, e.g. in the body cuticle and in specific cuticular markings (e.g., various arthropods: LAWRENCE 1954; isopods: ZIMMER et al. 2002; GIURGINCA et al. 2015; harvestmen: ACOSTA 1983, spiders: ANDREWS et al. 2007; scorpions: LAWRENCE 1954; KLOOCK 2005; the millipede *Paraspilobolus lucifugus*: MEYER-ROCHOW, pers.com., etc.). This endogenous fluorescence is often related to the protein component of the cuticle (ZILL et al. 2000) of which one of the most widespread is resilin (e.g. NEFF et al. 2000; WIESENBORN 2001; MICHELS & GORB 2012). But other fluorescent compounds such as the alkaloid β-carboline and 7-hydroxy-4-methylcoumarin have been identified, e.g. in the epicuticle of scorpions (STACHEL et al., 1999; FROST et al. 2001). Yet, there is still no empirical evidence that neither conspecifics of *L. verrucosa* nor any other organisms respond to the spot fluorescence. Some authors believe that autofluorescence is an intrinsic property of arthropod exoskeletons without any functions (STACHEL et al. 1999; MAZEL

2007). It has, however, been known that cockroaches representing the genera *Periplaneta* and *Blatta* possess UV and green receptors in their eyes (Mote & Goldsmith 1970; Mazokhin-Porshnyakov & Cherkasov 1985).

Autofluorescence and UV-reflectance of the spots covering cuticle of *L. verrucosa* are obscured by the carotenoid content of the underlying fat body. If this carotenoid-rich tissue is removed, transparency of the cuticle is evident, but the cuticle retains to some extent both, the UV-reflectance and the autofluorescence. We do not want to overestimate the minor differences in UV-reflectance between the previously red and white spots, which are probably due to the technique used. However, the differences between the autofluorescence of white spots with and without the underlying tissue are obvious. Currently we cannot exclude an indirect or direct contribution of the underlying tissue to the autofluorescence and UV-reflectance properties.

Apart from the fact that an accumulation of carotenoids is per se advantageous for *L. verrucosa* males and any other animal considering the physiological importance of these pigments (see literature cited above), the suggestion that they may be used for intraspecific communication appears plausible. It is undisputed that the spots are a clearly visual carotenoid-based signal, which differ in their color intensity depending on the condition of the males. However, this signal can be detected only if conspecifics have the appropriate receptors to do this.

Nothing is known about the visual capacity of *Lucihormetica* spp.. However, retinula cells of the likewise nocturnal cockroach *Periplaneta americana* are highly adapted to low light levels (e.g. Heimonen et al. 2006) and have sensitivity peaks in the green (approx. 507 nm) and UV (approx. 365 nm) range of wavelengths (Mote & Goldsmith 1970; see also *Blatta germanica,* Koehler et al. 1987). *Lucihormetica* spp. seem to be largely nocturnal (see Zompro & Fritzsche 1999; Dittrich et al. 2015). We can therefore assume *Lucihormetica* spp. to have a similar visual system like *P. americana* and *B. germanica*. Since cockroaches appear to have no red-sensitive type of photoreceptor (Mote & Goldsmith 1970; Koehler et al. 1987), the pronotum-spots of males appear, contrary to expectation, less conspicuous if they are red than if they are whitish. If *Lucihormetica* spp. had the same photoreceptor equipment as other cockroach species, they would be able to distinguish between well fed, healthy 'red' males and less well-fed, less healthy 'white' males. It is remarkable, that the perceptible signals would not come from the 'most attractive', reddest males. Regarding the putative superiority of 'red' males, behavioral studies on male-male interactions did not yield any clear results (unpublished), but unpublished data show a significant correlation between the green component of the color of the spots and the attractiveness of the males for females. This fits the known photoreceptor sensitivity in the compound eye of the cockroaches. Further investigations and experiments should be carried out for a better understanding of the visual system of the glow-spot cockroaches and to determine the functional significance of the spots more precisely. It is also possible, that different (or additional) photoreceptor cells have developed in *Lucihormetica* spp. from those present in other genera of cockroaches, e.g. *Periplaneta*. The evolution of photoreceptors is, in most cases, overarching to include all genera of a family, but e.g. in some species of bees additional receptors have also been developed (Briscoe & Chittka 2001).

Acknowledgement

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