UNIVERSITY OF AMSTERDAM

UvA-DARE (Digital Academic Repository)

Light or flight?

The impact of artificial light at night on insect predation risk

Broeckx, H.D.

Publication date
2026

Link to publication

Citation for published version (APA):
Broeckx, H. D. (2026). *Light or flight? The impact of artificial light at night on insect predation risk*. [Thesis, fully internal, Universiteit van Amsterdam].

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, P.O. Box 19185, 1000 GD Amsterdam, The Netherlands. You will be contacted as soon as possible.

UvA-DARE is a service provided by the library of the University of Amsterdam (https://dare.uva.nl)

Download date:10 Nov 2026

Summary

Artificial light at night (ALAN) currently affects at least 23% of the Earth's land surface. ALAN strongly changes the natural night environment, obscuring light–dark cycles and celestial cues, with far-reaching consequences for animals and plants. This happens because plants and animals use these celestial cues to orient themselves and follow the light–dark cycle to time their internal processes and behaviours. Since ALAN disrupts these natural signals, ALAN can affect populations and community interactions. ALAN is now seen as one of the major drivers of the alarming insect declines observed today.

In this thesis, I investigated how ALAN may contribute to insect declines by altering predator-prey interactions. I assessed how ALAN affects predation pressures by both vertebrate and invertebrate predators. In addition to predation pressures, I examined how predator and prey activities varied in both space (where) and time (when), and how these changes in activities relate to the prey's anti-predator colouration and behaviours.

In **Chapter 2**, I first examined the effects of dim light pollution (1.5 lux, 5500K) on caterpillar behaviour in the absence of predators. Specifically, I tested larval behaviours in three lepidopteran species differing in larval anti-predator colouration and adult activity period: *Mamestra brassicae* (Noctuidae; cryptic, nocturnal), *Pieris napi* (Pieridae; cryptic, diurnal), and *Pieris brassicae (*Pieridae; aposematic, diurnal).

As larval activity patterns are poorly studied, I first tested whether larval activity patterns coincide with adult activity patterns. I found that *M. brassicae* and *P. brassicae* larval activity patterns matched their adult activity patterns, while activity patterns of the cryptic *P. napi* larvae were mostly nocturnal and thus did not match their diurnal adult activity pattern. These results suggest that larval activity is more closely tied to larval colouration than to adult activity period, as both cryptic species were primarily nocturnal, while the aposematic species was diurnal.

By observing the three species on live plants over a full 24-hour cycle in dark and ALAN conditions, I found that all species were affected by ALAN, but in species-specific ways. Under dim ALAN conditions, the aposematic, diurnal *P. brassicae* caterpillars exposed themselves more on top of the leaves, whereas the cryptic, nocturnal *M. brassicae* caterpillars hid more underneath the leaves. These opposing behaviours can be linked to their anti-predator colours. Moreover, *M. brassicae* rested more under ALAN, consistent with expectations for a nocturnal, cryptic species. In contrast, the cryptic, nocturnal *P. napi* caterpillars responded in a more puzzling way: under ALAN, larvae moved more at night and fed more during the day, a pattern that does not align with expectations for a cryptic, nocturnal species. In a complementary experiment, I measured feeding activity on differently orientated leaf disks. The caterpillars showed a general preference for feeding on the upper leaf surface, supporting the interpretation

that *M. brassicae* uses the lower side primarily to hide. This experiment also revealed an overall increase in nocturnal feeding under dim light in all three species, a pattern that I did not detect in the on-plant experiment. Together, these results demonstrate that even dim ALAN can alter caterpillar behaviour in ways that likely affect their fitness and exposure to predators.

To test the consequences for predation risk, in **Chapter 3** I focused on *M. brassicae*, which showed the strongest behavioural shifts. In this chapter, I examined the effect of ALAN on predation pressure in two complementary experiments. To assess whether changes in predator and prey behaviour translate into changes in predation rates, we conducted an indoor experiment in which *M. brassicae* caterpillars were exposed to great tits (*Parus major,* Paridae) under either dark night conditions or dim ALAN (1.5 lux, 2700 K). I found that even though great tits were more active at night and started their activity earlier under ALAN, their predation rates on caterpillars did not increase. Possibly, the light level was too low for the tits to efficiently forage. Caterpillar feeding and hiding behaviour did not differ between light treatments, although larvae hid more in response to predator presence, which likely also affected the bird's foraging efficiency. In addition, to determine the role of anti-predator colouration in prey caterpillars, we quantified community-wide predation rates on cryptic and aposematic caterpillar models in the long-term Light on Nature sites, which consist of illuminated (7.6 lux, 2700 K) and dark forest transects. I found that predation rates on both cryptic and aposematic models did not differ between illuminated and dark transects. Possibly, long-term light exposure may diminish short-term predation increases that are generally found under ALAN. Overall, our results show that changes in predator activity in response to ALAN may not result in changes in predation rates and suggest that long-term light exposure may not increase predation rates as seen in studies with short-term illumination.

In **Chapter 4**, I examined whether nocturnal light of varying intensities and spectra (10 lux, 5500 K; 100 lux, 5500 K; 100 lux, 2700 K) affect predator behaviours. I focused on a visually oriented diurnal arthropod predator, the jumping spider *Marpissa muscosa* (Salticidae). I found that *M. muscosa* extends its activity into the night only under high-intensity, cold white light (100 lux, 5500 K). I also found that *M. muscosa* effectively forages under this nocturnal light condition, while bright, warm white light (100 lux, 2700 K) increased its overall sheltering behaviour. These findings suggest that *M. muscosa* is sensitive to ALAN, but that effects may be restricted to areas close to light sources or to high-intensity lights.

In **Chapter 5**, we assessed whether dimming urban streetlights is an effective mitigation strategy to reduce ALAN impacts on flying insects and *Pipistrellus spp.* (Vespertilionidae) bats by monitoring their activity over one month under dimmed (4.4 lux, 3000 K) and undimmed (17 lux, 3000 K) streetlights and at dark locations in two Dutch cities. Dimming streetlights effectively reduced insect attraction, although

insect densities remained higher than in dark areas and insect activities throughout the night still showed slight shifts in lit conditions. Unexpectedly, pipistrelle bats did not react to light dimming and their activity patterns throughout the night were generally unaffected by light. This suggests that urban pipistrelle bats differ in their response to light than bats in less urbanised landscapes, where pipistrelles often exploit high insect densities around streetlights. Together, our results indicate that dimming urban streetlights reduces insect attraction, which thus benefits insect populations, and thereby bats, over longer timescales. Further, our findings also underscore that darkness is crucial not only in natural, but also in urban habitats.

Finally, to try to streamline insect monitoring by applying AI methods, in **Chapter 6** we customised an open-source object detection model. Using the insect data collected in **Chapter 5**, we validated the model by comparing manually scored detections with the model's automated detections, and assessed how ambient light conditions and temporal resolution influenced model performance. We found that automated detection greatly speeds up the detection of insects, although insect detection was less effective in darkness. We also found a decline in model performance and an increased sensitivity to illumination when the model was used over shorter time intervals. These findings indicate that automatisation processes can be a great help to lower the manual labour of ecological insect monitoring and increase data processing speed. However, these methods should be applied with caution, whereby selecting the study design and objectives are crucial

Samenvatting

Nachtelijk kunstlicht beïnvloedt inmiddels minstens 23% van het landoppervlak op aarde. Lichtvervuiling verandert het nachtelijke landschap ingrijpend: het vervaagt de licht-donker cyclus en maakt hemellichamen minder zichtbaar, wat grote gevolgen heeft voor dieren en planten. Zij gebruiken deze natuurlijke signalen immers om zich te oriënteren en hun gedrag en interne processen af te stemmen. Door deze verstoring kunnen hele populaties en gemeenschappen worden beïnvloed. Lichtvervuiling wordt tegenwoordig gezien als een belangrijke oorzaak van de wereldwijde achteruitgang van insecten.

In dit proefschrift onderzocht ik hoe lichtvervuiling, via verstoring van predator-prooirelaties, kan bijdragen aan de insectenafname. Ik keek naar de invloed van nachtelijk kunstlicht op predatiedruk door zowel gewervelde als ongewervelde predatoren. Daarnaast onderzocht ik hoe de activiteiten van predatoren en prooien varieerden in ruimte (waar) en tijd (wanneer), en hoe deze veranderingen samenhangen met de anti-predator kleur en het gedrag van de prooi.

In **Hoofdstuk 2** onderzocht ik eerst de effecten van zwak kunstlicht (1,5 lux, 5500K) op het gedrag van rupsen zonder aanwezigheid van predatoren. Ik testte het gedrag van rupsen van drie vlindersoorten die verschillen in anti-predator kleur en activiteit van de volwassen vlinders: *Mamestra brassicae* (cryptisch, nachtactief), *Pieris napi* (cryptisch, dagactief) en *Pieris brassicae* (aposematisch, dagactief).

Omdat er weinig bekend is over de activiteitspatronen van rupsen, onderzocht ik of deze overeenkomen met die van de volwassen vlinders. De activiteit van *M. brassicae* en *P. brassicae* rupsen kwam overeen met die van de adulten, terwijl de cryptische *P. napi* rupsen vooral 's nachts actief waren, wat niet overeenkwam met het dagactieve patroon van de adulten. Dit suggereert dat het activiteitspatroon van rupsen meer samenhangt met hun kleur dan met het activiteitspatroon van de adulten.

Door de drie soorten gedurende een volledige 24-uurs cyclus op levende planten te observeren onder donkere en verlichte nachtelijke condities, bleek dat alle soorten werden beïnvloed door kunstlicht, maar elk op een eigen manier. Onder zwak kunstlicht lieten de aposematische, dagactieve *P. brassicae* rupsen zich meer zien bovenop de bladeren, terwijl de cryptische, nachtactieve *M. brassicae* rupsen zich juist meer onder de bladeren verstopten. Deze tegengestelde gedragingen zijn te koppelen aan hun anti-predator kleuren. Bovendien rustte *M. brassicae* meer wanneer de nacht verlicht werd, wat past bij een cryptische, nachtactieve soort. De cryptische, nachtactieve *P. napi* rupsen reageerden juist onverwacht: onder kunstlicht bewogen ze meer 's nachts en aten ze meer overdag. In een aanvullend experiment heb ik de

eetactiviteit op verschillend georiënteerde bladschijfjes gemeten. De rupsen hadden een duidelijke voorkeur om te eten aan de bovenkant van het blad, wat ondersteunt dat *M. brassicae* de onderkant vooral gebruikt om zich te verstoppen. Ook nam het nachtelijke eetgedrag bij alle drie de soorten toe onder zwak kunstlicht, een patroon dat ik niet vond in het experiment met rupsen op de planten. Samen laten deze resultaten zien dat zelfs zwak nachtelijk kunstlicht het gedrag van rupsen kan veranderen op manieren die waarschijnlijk hun fitness en blootstelling aan predatoren beïnvloeden.

Om de gevolgen voor predatierisico te testen, heb ik me in **Hoofdstuk 3** gericht op *M. brassicae*, die de sterkste gedragsveranderingen liet zien. In dit hoofdstuk onderzocht ik het effect van lichtvervuiling op predatiedruk in twee complementaire experimenten. Om te beoordelen of veranderingen in het gedrag van predatoren en prooien leiden tot veranderingen in predatie, voerden we een indoor experiment uit waarin *M. brassicae* rupsen werden blootgesteld aan koolmezen (*Parus major*) onder donkere of zwak verlichte nachtcondities (1,5 lux, 2700 K). Ik vond dat koolmezen in verlichte nachten actiever waren en hun activiteit eerder begonnen, maar dat hun predatie op rupsen niet toenam. Mogelijk was het lichtniveau te laag voor de koolmezen om efficiënt te foerageren. Het eet- en verstopgedrag van de rupsen verschilde niet tussen de lichtbehandelingen, hoewel larven zich meer verstopten in aanwezigheid van predatoren, wat waarschijnlijk ook de foerageerefficiëntie van de vogel beïnvloedde. Om vervolgens ook de rol van anti-predator kleur te bepalen, hebben we predatie op cryptische en aposematische kleien rupsen gemeten in de langlopende Licht op Natuur locaties, bestaande uit verlichte (7.6 lux, 2700 K) en donkere bostransecten. Ik vond dat de predatie op zowel cryptische als aposematische modellen niet verschilde tussen verlichte en donkere transecten. Mogelijk vermindert langdurige blootstelling aan licht de kortstondige toename van predatie die doorgaans wordt gevonden onder verlichting. Onze resultaten laten zien dat veranderingen in predatoractiviteit als reactie op kunstlicht niet altijd leiden tot veranderingen in predatie, en suggereren ze dat langdurige blootstelling aan licht predatie niet verder verhoogt zoals gezien wordt in studies met kortdurende verlichting.

In **Hoofdstuk 4** onderzocht ik of nachtelijk licht van verschillende intensiteiten en spectra (10 lux, 5500 K; 100 lux, 5500 K; 100 lux, 2700 K) het gedrag van predatoren beïnvloedt. Ik richtte me op een visueel georiënteerde, dagactieve geleedpotige predator, de springspin *Marpissa muscosa*. Ik vond dat *M. muscosa* haar activiteit alleen uitbreidt naar de nacht onder fel, koud wit licht (100 lux, 5500 K). Ook bleek dat *M. muscosa* effectief foerageert onder deze nachtelijke lichtconditie, terwijl fel, warm wit licht (100 lux, 2700 K) haar schuilgedrag juist vergrootte. Deze bevindingen suggereren dat *M. muscosa* gevoelig is voor lichtvervuiling, maar dat de effecten

beperkt zouden kunnen zijn tot gebieden dicht bij lichtbronnen of bij hoge lichtintensiteit.

In **Hoofdstuk 5** onderzochten we of het dimmen van straatverlichting een effectieve mitigatiestrategie is om de impact van kunstlicht op vliegende insecten en dwergvleermuizen te verminderen. We monitorden hun activiteit gedurende een maand onder gedimde (4.4 lux, 3000 K) en niet-gedimde (17 lux, 3000 K) straatverlichting en op donkere locaties in twee Nederlandse steden. Dimmen van straatverlichting verminderde de aantrekkingskracht op insecten, hoewel de insectendichtheid toch nog steeds hoger bleef dan in donkere gebieden en de activiteit van insecten gedurende de nacht ook enigszins verstoord was in verlichte omstandigheden. Verrassend genoeg reageerden dwergvleermuizen niet op het dimmen van het licht en hun activiteitspatronen gedurende de nacht werden niet beïnvloed door de straatverlichting. Dit suggereert dat stedelijke dwergvleermuizen anders reageren op licht dan vleermuizen in minder stedelijke gebieden, waar ze vaak profiteren van hoge insectendichtheid rond lantaarnpalen. Onze resultaten tonen aan dat het dimmen van straatverlichting in steden insectenaantrekking vermindert, wat insectenpopulaties ten goede komt en op termijn ook vleermuizenpopulaties kan ondersteunen. Daarnaast onderstrepen onze bevindingen dat duisternis niet alleen in natuurlijke, maar ook in stedelijke habitats van cruciaal belang is.

Tot slot, om insectenmonitoring te stroomlijnen met AI-methoden, hebben we in **Hoofdstuk 6** een open-source objectdetectiemodel gemodificeerd voor onze doeleinden. Met de insectendata uit **Hoofdstuk 5** valideerden we het model door handmatig gescoorde detecties te vergelijken met de automatische detecties van het model, en onderzochten we hoe omgevingslicht en temporele resolutie de modelprestaties beïnvloeden. We vonden dat automatische detectie het tellen van insecten aanzienlijk versnelt, hoewel detectie minder effectief was in het donker. Daarnaast bleek dat, bij toepassing op kortere tijdsintervallen, de modelprestaties verminderden en de invloed van licht toenam. Deze bevindingen laten zien dat automatisering een grote hulp kan zijn om de handmatige arbeid bij ecologische insectenmonitoring te verminderen en de snelheid van dataverwerking te verhogen. Wel moeten deze methoden met voorzichtigheid worden toegepast, waarbij het studieontwerp en de doelstellingen van de studie cruciaal zijn.

Author contributions

Chapter 2: Artificial light at night alters caterpillar behaviour

Hannah D. Broeckx, Anne N. Haringhuizen, Alanna L. Brown, Emily R. Burdfield-Steel, Astrid T. Groot

HDB, ERB, ATG contributed to the design and conceptualisation of the study. All authors contributed to the data collection. HDB analysed the data, with the assistance of ERB. HDB wrote the first draft. ERB and ATG contributed to the revisions. All authors approved the submitted manuscript.

Chapter 3: Artificial light at night does not increase caterpillar predation

Evidence across birds and forest communities under short- and long-term exposure

Hannah D. Broeckx, Barbara M. Tomotani, Marcel E. Visser, Astrid T. Groot, Kamiel Spoelstra, Emily R. Burdfield-Steel

HDB, MEV, ATG, ERB, KS contributed to the design and conceptualisation of the study. BMT and MEV provided the experimental great tits and helped with the necessary licenses. HDB performed the experiment with the assistance of ATG and KS. HDB analysed the data, with the assistance of ERB. HDB wrote first draft. BMT, MEV, ATG, KS and ERB contributed to the revisions. All authors approved the submitted manuscript.

Chapter 4: Artificial light at night alters jumping spider behaviour: the role of light intensity and spectral composition

Hannah D. Broeckx, Gabriel A. Charvalakis, Astrid T. Groot, Emily R. Burdfield-Steel

HDB and ERB contributed to the design and conceptualisation of the study. HDB and GAC contributed to the design and conceptualisation of the automated tracking algorithm. HDB performed the experiment. HDB analysed the data, with the assistance of ERB. HDB wrote the first draft. GAC, ATG and ERB contributed to the revisions. All authors approved the submitted manuscript.

Chapter 5: Dimming streetlights in urban areas reduces insect attraction but pipistrelle bats forage more in darkness

Sander W.J. Buddendorf, Hannah D. Broeckx, Jona van Delft, Astrid T. Groot, Marcel E. Visser, Emily R. Burdfield-Steel, Kamiel Spoelstra

SWJB, HDB, ATG, MEV, ERB and KS contributed to the design and conceptualisation of the study. SWJB and HDB contributed to the data collection. SWJB curated bat data. HDB and JvD curated insect data. SWJB and HDB analysed the data. SWJB and HDB wrote the first draft. ATG, MEV, ERB, KS and ERB contributed to the revisions. All authors approved the submitted manuscript.

Chapter 6: AI-based assessment of insect temporal activity under different light conditions

Gabriel A. Charvalakis, Hannah D. Broeckx, Sander W.J. Buddendorf , Jona van Delft, Emily R. Burdfield-Steel, Roelof A. Hut & Kamiel Spoelstra

GAC, HDB, SWJB, ERB, RAH and KS contributed to the design and conceptualisation of the study. HDB and JvD curated the manual insect data. GAC trained the AI model and analysed the data. GAC wrote the first draft. HDB, SWJB, ERB, RAH and KS contributed to the revisions. All authors approved the submitted manuscript.

Author addresses

Department of Evolutionary and Population Biology (EPB), Institute for Biodiversity and Ecosystem Dynamics (IBED), University of Amsterdam, Science Park 904, Amsterdam, the Netherlands

Hannah D. Broeckx, Anne N. Haringhuizen, Alanna L. Brown, Emily R. Burdfield-Steel, Astrid T. Groot, Jona van Delft

Department of Animal Ecology, Netherlands Institute of Ecology (NIOO-KNAW), Wageningen, the Netherlands

Barbara M. Tomotani, Marcel E. Visser, Kamiel Spoelstra, Gabriel A. Charvalakis, Sander W.J. Buddendorf

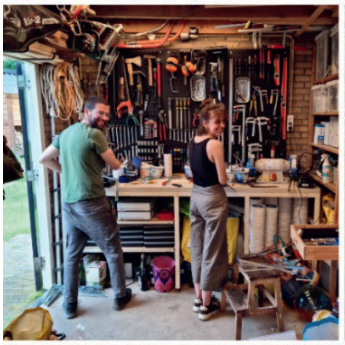
Groningen Institute for Evolutionary Life Sciences (GELIFES), Faculty of Science and Engineering, University of Groningen, Groningen, the Netherlands

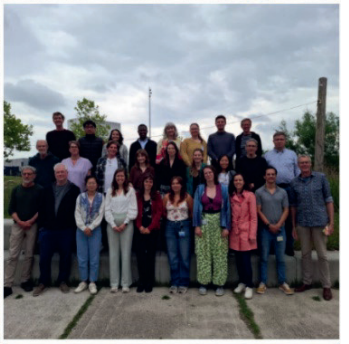
Marcel E. Visser, Gabriel A. Charvalakis, Sander W.J. Buddendorf, Roelof A. Hut

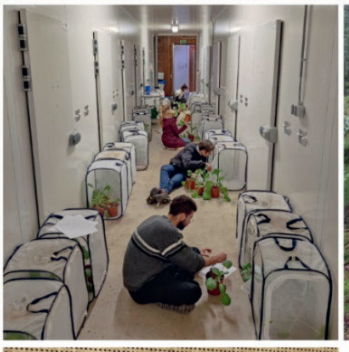
Department of Arctic and Marine Biology, UiT - The Arctic University of Norway, Tromsø, Norway

Barbara M. Tomotani

Dimming streetlights reduces insects' attraction but leaves bats in the dark
BIOCLOCK







Acknowledgements

None of my scientific findings are as clear as the finding that I could have never accomplished this without the help and support of so many people! At last, I can thank you all.

First and foremost, I am deeply grateful to my supervisors for guiding me through this insightful, yet challenging journey. **Astrid**, thank you for your energy, ideas and for always pushing me further. Writing was challenging as we have contrasting writing styles, but I have learned a lot from yours. So, I will keep my phrasing short this time and just write a simple "Thank you!". **Emily**, I want to truly thank you for your weekly guidance and close involvement in my project. You provided a safe space to share my insecurities and helped me keep perspective when I stressed over the details. I could not have done this without you both.

A huge thank you to everyone who provided me with practical help. Special thanks to **Eileen B.**, **Lisette**, **Wanda**, **Dennis**, **Taymaz, Peter K., Lin**, and **Melanie** for helping me rear my lab animals and helping me out with experiments. Thank you for bearing with me, when I rushed in for immediate help. Thanks to **Bas**, **Elmar**, **Clint** and **Mels** for the technical support. **Harold** and **Ludek**, thank you for growing my plants with great care, even when I asked for ridiculously large numbers in very short time windows. At NIOO, I want to thank **Maartje** for all the help with the great tit experiment, I could not have coped without you. I want to thank **Pieter**, **Jordy** and **Liana** for all the caterpillar eggs. These cuties (the caterpillars, not the people) kept me going for the full 24-hours! **Bryndan**, thank you for helping with the spider collection. Their bright eyes kept me happy through the many feeding hours. **Michiel** and **Emiel**, thank you for steadying my path through the statistical swamp. Of course, many others offered practical help, but I'll thank you all for being in my life in the next sections.

To all the EPB people, past and present, thank you for creating such a nice working atmosphere at Science Park. Thank you **Paul**, **Patrick M.**, **Hans**, **Michiel, Arne, Karline**, **Jonna**, **Willem**, **Naima**, **Marjolein B.**, **Thomas**, **Merijn**, **Martijn**, **Juan, Vincent, Ernesto, Amruta, Nicole, Stefan, Mobolade, Benjamin, Peter R., Dajo**, **Max** for the interesting meetings and discussions, for the useful feedback and help, and of course for the nice lunch breaks and EPB gatherings. **Gerard**, thank you for including me in the Ecology and Biodiversity course. I learned a lot from this teaching opportunity, and the excursions were a very good way to explore the Netherlands. Thank you **Christel**, **Marit**, **Isabel**, **Patrick K.**, **Xandra**, **Laura, Jacques, Rachid** for being part of this nice work environment, but also for the great times outside of work. You are all great fun! **Alexandra**, I always felt very at ease with you. You are a great and

kind person. I enjoyed witnessing you losing your English insecurity. Then, a special thanks to all my great office mates. **Masoumeh** and **Thanet**, the office was always nicer and more joyful when you were there. **Daan**, your rare office visits were always entertaining. You've always worn your heart on your sleeve, which I really liked. **Jiajia**, I really enjoyed our PhD time together. Our dumpling folding session was a highlight. **Julé, Marjolein T. and Marc**, our overlap was limited but I enjoyed those times non the less. I wish you all good luck with the rest of your PhD/postdoc! **Elise** and **Naomi**, although I only saw you at the start of my PhD, you immediately made me feel welcome. I still cherish our shared moments together. **Joan** and **Simone**, even though you were both only here for three months, I really enjoyed your company. I am really happy you left the Mediterranean weather to come and work here in Amsterdam. Simone, I don't know how you did it but in just three months you managed to become one of my favorite people. Also thanks to the non-EPB members, **Sascha**, **David**, **Wara**, **Or**, **Emma**, **Evy**, **Nan**, **Hans**, **Bart**, **Sara**, **Johannes**, **and many more**. Thanks for the shared moments!

To my corridor friends, **Geert** and **Edo**, thank you for showing interest in my progress and helping me out at the start of my project. I was always happy to see you at the ecological gatherings in Amsterdam. Edo, I especially enjoyed the moth and fish catching nights we spend together. I also learned a lot from those.

I am especially grateful to have been part of the BioClock consortium and would like to thank all of you! Our BioClock and Chronobiology days made me feel part of a vibrant community. **Laura** and **Georgiana**, you were incredible BioClock Academy partners. I especially want to thank all my dearest Cluster 3 colleagues. **Sander** and **Gabriel**, I very much enjoyed our shared projects, and it was nice to share our struggles. Of course, I also need to thank you both for helping me out with experiments, as I apparently have a predilection for big experimental designs. **Evelien**, you were also part of this starting gang. Unfortunately, we did not see each other that much, but every time we did, I felt very much at ease in your company. I enjoyed our times in the field together and took great lessons of how you stand in life and in your PhD. **Maaike** and **Marvin,** I am very happy you joined the team later on, your fresh enthusiasm was inspiring, and I enjoyed the conferences where we had some more time together. **Ivanka**, you got me through the first year of my PhD. I really enjoyed our time together and I am still sad it had to end so soon but maybe, one day, we will meet at the RAVON day! **Dani** and **Anouk** even though we mostly met online or at the BioClock progress meetings, I always enjoyed seeing you. A big thanks to **Jona** and **Salina** for your invaluable work in going through all the insect footage. I would never have managed without you. Jona, your help in the field was also highly appreciated. How much fun did we have camping, right?! **Koen**, I also enjoyed our very short working period together. **Kamiel**, thank you for leading our cluster, offering valuable advice, and supporting me

throughout many of my experiments. **Marcel**, I'm grateful for the opportunity to conduct my first real experiment at NIOO, the first data I could actually add to my thesis.

I am also very grateful for the opportunity to supervise students. **Jip**, thanks for being my first student. As I had just started myself, we really had to work things out together, but I think you were the perfect student to do this with. In the end, your project was invaluable to learn what trapping methods did NOT work. I would also like to thank you for the later scientific outreach opportunities you gave me. **Alanna,** thank you for your optimism throughout the project. We had a good laugh over our sleep deprivation during the first 24-hour experiments, gathering the data for Chapter 2. **Britte** and **Anne,** thanks for withstanding the cold and bringing the first trials of the model predation experiment to a good end. Your efforts are immortalised in Chapter 3. Although being forced together, you formed a great team and it was fun to watch you two. Thanks also for your help in the lab, in the spider and caterpillar experiments. Although the spider data could not be used, these first trials did teach me a lot for the later experiments in Chapter 4. The caterpillar data contributed nicely to Chapter 1. **Eve**, you really won the lottery with your project, right!? Thanks for your endurance with the insect footage. Your work contributed to Chapter 5, my first published article. **Sarah,** you were a very bright bachelor student. Thank you for laying at the basis of my later model predation experiments. **Skip**, **Imre**, **Michelle** and **Sterenn**, I was less involved in your supervision, but I enjoyed our encounters and learned a little bit from each of you.

I also want to thank my dearest Amsterdam people. We started off as colleagues, but soon you became my closest friends. I am very sure I would have never finished this PhD if I did not have all your great company around me. **Renée,** you were the one showing me around after the job interview and even with the covid mask you managed to make me immediately feel at home. Your openness and enthusiasm make you a wonderful person. I'm very grateful to have had you as my desk mate, your presence always brightened my day. **Giudi**, from the very beginning, you've been the driving force behind my social life. You are always so inclusive and kind. Even from the far north, you're the one who keeps our group connected. I truly appreciate your energy and creative spirit. **Edith,** your generous heart shines through in the way you organise the biggest and most fun parties, connect people, but how you are also always up for smaller get-togethers, niche concerts, and creative events. I am very happy we shared the start and end of our PhDs. **Eileen E.**, honestly I think you are one of the coolest people I know, especially since you don't seem to realise it yourself. You are so generous and funny, it's ridiculous. Thanks, protest buddy! **Nina,** somehow our paths did not often cross in the beginning, but over time I learned what a kind, warmhearted and amazing person you are. I also look up at the amazing work you do, your care and

passion for the nature and people of the Amazon is so inspiring. **Karla**, as a whirlwind you entered my life. I love your endless energy and big smile. Your enthusiasm tilted record buying, thrift shopping and watching movies to a new level. You are so kind and engaging to everyone around you. Even my rat Liva (or Liefie, as you liked to call her) felt your love when she was sick. **Shreyas** thanks for being my cycling partner for a long time. I always enjoy your company, as you are such an open and kind person. Westies forever!

I also want to thank my sweet Belgian (but nowadays quite international) friends who made sure I would always be missing something here in Amsterdam. Thank you **Ine** and **Myrthe** for making my biology studies much more enjoyable, maybe I would have never made it to the start of my PhD without you. I love all our moments together, from getting pierced to a full day of crafting. I am very glad we met on that very first day. **Helena** and **Hannah**, for more than 15 years we have know each other. Our friendship definitely did not start on the first day, but it grew to immeasurable proportions. I would never have been the person I am now without you. I hope to have you back one day, Hannah. Helena, I am very happy the distance only brought us closer. You have been an invaluable friend to me, especially in these last few years. Crafting and going to concerts eased the burden of adult life. **Robbe** and **Bert**, thanks for regularly checking in. This meant a lot to me, even though I always failed to remember to check in on you. I always enjoyed meeting up with you guys. **Noga,** I cherish your postcards and loved your visits here in Amsterdam. Even though we do not see each other that often, I know I have a true friend in you.

Lastly, I want to thank **my family** for believing in me and sharing an interest in my work. I especially want to thank my parents, **Kristien** and **Walter**, for fostering my creativity and passion for nature from a young age. Also thank you for “rubberducking” and helping me to communicate my science and my thoughts to the world.

If I forgot anyone, please don’t take it personal. Let’s blame it on the brain fog that arised from writing this thesis…

About the author

Hannah David Broeckx was born on September 11, 1998, in Dendermonde, Belgium. Growing up with a large garden, she developed an early fascination with nature. She spent her childhood collecting bones, monitoring garden wildlife, observing chickens as they laid eggs, and even conducting her first (though poorly replicated) plant experiments. From the start, there was no other option than to become a biologist.

In 2016, Hannah began her Bachelor's in Biology at the University of Ghent. Finally she felt a sense of belonging. She completed her bachelor's thesis on "The effect of urbanisation on colour polymorphism in weevils" under the supervision of Bram Vanthournout. She continued with a Master's in Global Change Ecology. During her master's, Hannah spent a semester abroad at NTNU in Trondheim, Norway, which broadened her horizons and revealed opportunities beyond Flanders. Back in Belgium, she completed her master's thesis on "An evaluation of agri-environment schemes to increase arthropod biodiversity and abundance" under Luc De Bruyn's guidance, and undertook a short internship on sustainable milk farming at ILVO with Veerle Van linden. In 2021, Hannah obtained her Master's degree and was finally awarded the title of biologist.

Driven by her passion for living things and her desire to reduce human impact on nature, Hannah found her first big project in 2022: tackling the issue of artificial light at night. With determination, she set out to Amsterdam, to protect the natural world she loves.

As her work progressed, she had to recognise that the reach of her scientific research alone would stay small. She therefore chose to broaden her impact by integrating public awareness, responsible personal behaviour and targeted activism, alongside her research. Having established this foundation, she is now ready to define and pursue a new project.

PE&RC Training and Education Statement

With the training and education activities listed below the PhD candidate has complied with the requirements set by the Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 30 ECTS (= 22 weeks of activities)

Review/project proposal

- The influence of artificial light at night on insect-predator interactions | 4.5 ECTS

In-depth / Topical / On-site Postgraduate Courses

- Bugs at your service | PE&RC | 2023 | 1.5 ECTS
- InsectAI | Department of Ecoscience and the Centre for Quantitative Genetics and Genomics, Aarhus University | 2025 | 2 ECTS

Methodological / Statistical Postgraduate Courses

- Generalized Linear Models | PE&RC | 2024 | 0.9 ECTS
- Mixed Linear Models | PE&RC | 2024 | 0.6 ECTS

Invited review of journal manuscripts

- Ecological Entomology | Moth mating under different light scenarios | 2024 | 1 ECTS

Competence, skills and career-oriented activities

- Mastering your PhD | UvA & Reflect Academy | 2023 | 0.75 ECTS
- Time management | UvA & Tijdswinst | 2023 | 0.3 ECTS
- Workshop Zotero | UvA | 2023 | 0.15 ECTS
- Introduction to LaTex | PE&RC | 2024 | 0.15 ECTS
- Career workshop | P(h)D councils of IBED, SILS and HIMS & FNWI career services | 2024 | 0.15 ECTS
- Workshop communication | BioClock | 2023 | 0.15 ECTS
- Module 1 You as a teacher | UvA-FNWI | 2022 | 0.15 ECTS
- Module 2 Didactical skills | UvA-FNWI | 2022 | 0.15 ECTS
- Module 3 The learning environment you create | UvA-FNWI | 2022 | 0.15 ECTS
- Module 4 You and the group | UvA-FNWI | 2022 | 0.15 ECTS
- Module 6 Tailor your supervision style | UvA-FNWI | 2023 | 0.15 ECTS

Scientific Integrity/Ethics in science activities

- Scientific integrity (as part of Mastering your PhD) | UvA & Reflect Academy | 2023 | 0.15 ECTS

- Ethics and Animal science | WUR | 2023 | 0.8 ECTS

PE&RC Retreat, PE&RC Day, and other PE&RC events

- PE&RC First year retreat | 2023 | 0.9 ECTS
- PE&RC Midterm retreat | 2024 | 0.6 ECTS
- PE&RC Last year retreat | 2025 | 0.6 ECTS

National/local scientific meetings, seminars, and discussion groups

- Future for butterflies and moths | 2025 | 0.6 ECTS
- NAEM (poster) | 2023 | 0.6 ECTS
- NAEM (PPT) | 2024 | 0.6 ECTS
- Entomologendag (poster) | 2022, 2023, 2024 | 0.9 ECTS
- Dutch Chronobiology meeting | poster in 2023, host in 2024, talk in 2025 | 0.9 ECTS
- Evolving urban communities symposium | 2024 | 0.3 ECTS
- Landelijke dag Vlinderstichting | 2023 | 0.3 ECTS
- Nationale Vlinderdag | 2023 | 0.3 ECTS
- Academische Tafel over licht en urban ecology | 2023 | 0.1 ECTS
- Academische Tafel aftrap Darkfestival | 2023 | 0.1 ECTS
- Academische Werkplaats Urban Ecology | 2024 | 0.1 ECTS

International symposia, workshops and conferences

- Behaviour (PPT) | Bielefeld, Germany | 2023 | 2.8 ECTS
- ALAN conference (PPT) | Westport, Ireland | 2025 | 1.9 ECTS

Societally relevant exposure

- Night walk for VOX-POP | 2024 | 0.1 ECTS
- Interview Folia | 2024 | 0.1 ECTS
- BioClock municipality meeting (PPT) | 2025 | 0.3 ECTS

Committee work

- BioClock Academy seminar committee | 2022-2025 | 4 ECTS

Lecturing/Supervision of practicals/tutorials

- Plant-Soil interactions | 2022 | 5 days | 1.5 ECTS
- Biodiversity and Ecology | 2022, 2023, 2024 | 16 days | 4.8 ECTS
- Evolutionary genetics | 2024 | 1 days | 0.3 ECTS
- Keystone II | 2024 | 1 days | 0.3 ECTS

BSc/MSc thesis supervision

- Research topic 1: Light Pollution affects Local Moth Community Composition | 3 ECTS

- Research topic 2: Evaluating the influence of Artificial Light at Night (ALAN) on caterpillar predator-prey dynamics and caterpillar behaviour across distinct colouration strategies and activity patterns | 2 ECTS
- Research topic 3: Shining a Light on Predator-Prey Interactions: Artificial Light at Night Affects the Behaviour of Both Caterpillars and Their Predators | 1 ECTS
- Research topic 4: The effect of artificial light at night on predator community | 0 ECTS
- Research topic 5: Illuminating Changes: The Effect of Urban Light Pollution on Flying Insects | 0 ECTS
- Research topic 6: The Effect of Light Pollution on Anti-Predator Coloration Strategies in the Lepidoptera Species *Z. filipendulae* and *M. brassicae* | 0 ECTS
- Research topic 7: Feeding the Nestlings: caterpillar biomass as a determinant of Great and Blue tits breeding success along an urban gradient | 0 ECTS