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State Exam Thesis in the Subject of Biology

"Biological Analyses of honeybee associated Pseudoscorpions (*Chelifer cancroides*)"

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1. Introduction

Since the early summer of 2007, I intensively engaged myself in the potentially biggest modern problem in bee keeping- the infestation of *Apis mellifera* with the parasite *Varroa destructor*, a mite that is causing an approximate agricultural damage of about 15 million Euros per year in Germany alone. (1) The varroa mite is linked to the annual killing of 25% of all bee populations worldwide. Thus, the damage is millions of Euros. The aim is to develop a sustainable solution for the problem. Therefore, this work is focusing on the biological fight against the varroa mite using natural enemies. I got inspired to this work through an article about the fire ant, which spread throughout America as a neozoan since 1920. Indeed, there are many similarities, for example the human approach to bring the fire ant problem under control using numerous pesticides and the consequential development of stronger ants with various resistances. Finally, the humpbacked flies were imported into the USA in a pilot project- a natural enemy that is supposed to bring the ants under control…

The *Varroa constructor* was also fought with numerous chemicals and developed resistances in the course of the past 30 years. The result of the harsh selection conducted by humans is that the varroa mite is much more vital and resistant nowadays than ever before. In fact, bee researchers assume that nowadays ten times less mites are required in order to kill a bee population than in the 1990's (2). My research analyzes the possibility to fight off the vermin of the bees using *Chelifer cancroides* – a pseudoscorpion that is home to Europe and used to be co-living with bees. Up until now, based upon contradictory statements in the literature, it was unclear if *Chelifer cancroides* eats mites at all. Additionally, it has never been researched if *C. cancroides* is able to pose a threat to an armored mite like *Varroa constructor*. Especially in older literatures, the book scorpion is described as a beneficial animal inside the beehive, because it eats most of the varmints of bees and does not do any harm to the bees themselves. Nevertheless, *Chelifer cancroides* was mostly overlooked in beekeeping and its role as a biological fighter of varmints was barely looked at. Over the course of the process of modernization of beehives the interests of pseudoscorpions were not considered. Therefore, nowadays they do not have any habitat inside of modern beehives and can barely be found there anymore. In that way the eight-legged, pincher bearing spider animals were forgotten about more and more. However, there are some

researchers, who noticed that in wild bee populations, housing pseudoscorpions, no varmints of bees were able to be found. The observations suggest that there is the possibility that the number one varmint of bees, the varroa mite, can be brought under control with the help of the pseudoscorpions. Therefore, not only the reasons for the absence of pseudoscorpions in European beehives are analyzed, but the focus is also put on the prerequisites and the perspective of a successful re-establishment. The aim of this research is to determine in experiments which behaviors *Chelifer cancroides* possesses and which abiotic and biotic conditions must be fulfilled in order for the pseudoscorpion to successfully reproduce and proliferate. Therefore, first of all, these animals had to be found, which was challenging due to the lack of literature about *Chelifer cancroides*. When the question regarding its habitation was solved after months, the pseudoscorpions were bred and a number of analyses were performed. These analyses were supposed to clarify whether *Chelifer cancroides* takes on varroa mites as prey and which detailed modifications have to be made in modern beehives in order to provide a permanent habitation inside the beehive. If it would be a success to keep bee populations without the prevalent chemical remedies and to keep bees in a healthy state under biological control, this could sustainably change beekeeping and apiary worldwide.

a) The idea and literature

I found a few articles in online discussion forums that were written by beekeepers in 2005. One member of the discussion quoted an article from the magazine "New England Beekeper, July 2000, Vol-7, No-6". In the article it is described that a certain kind of pseudoscorpions in beehives in South Africa is able to keep the varroa mite at a low population so that no chemicals are necessary (3). This awoke my interest and I asked myself if these animals really exist and if a similar species can be found in our region. The research showed that nine different species are prevalent in Germany, which are divided in 49 subcategories (4). Soon thereafter, the book scorpion (*Chelifer cancroides*) was drawn to my attention. A pseudoscorpion that is, amongst others, described in the "Lexikon der Bienenkunde" published by Ehrenwirth-Verlag:

"Pseudoscorpions, especially book scorpion (Chelifer cancroides, order Arachnoid (spider animals), useful co-habitant inside the beehive. Approximately 6 mm in size with hefty pinchers (...), A. feeds off young wax moth larvae, bee lice, and trash mites inside the beehive" (5)

Fundamental questions:

If *Chelifer cancroides* is able to feed off of varroa mites, why was not a biological balance established as it is *allegedly* the case in Africa? Does *Chelifer cancroides* eat mites at all or do beekeepers prevent a natural enemy-prey relationship between Chelifer and Varroa by killing both individuals using frequent chemical treatments of the beehives? This postulation seemed likely, because both, mites and pseudoscorpions, belong to the class Arachnid and therefore have physiological similarities. I was also asking myself how high the rate pseudoscorpion offspring is and how long the development from the protonymph to the adult animal takes. With respect to a successful biological fight using the predator-prey relationship, this finding is important in order to estimate the ability of pseudoscorpions to react to a quickly reproducing mite population. Furthermore, obviously the number of mites that are eaten by one pseudoscorpion within a certain timeframe is important. Some of these questions were able to be clarified with the help of the current literature; others were analyzed during this research in experiments.

The book "Moos und Bücherskorpione" by Dr. Peter Weygoldt from 1966 served as a good theoretical foundation. It entails a good overview of the most common species of pseudoscorpions with respect to their behaviors, physiology, reproduction, development, and tips to catch, keep, and conserve them. In this book the following hint is found:

"All species rely on the availability of gaps and ridges. They live a hidden life and appear only where such shelters are available. (6)"

Additionally, in other reports and articles, book scorpions are described as markedly "gab-habitants". (7) In clear words, this means that beekeepers took away the habitat of *Chelifer cancroides* when they introduced modern, smoothly-walled wood as well as hard styrofoam beehives which came into fashion in the late 1970's. Furthermore, depending on the living

conditions, the development of *Chelifer cancroides* takes 10-24 month beginning from the egg to the adult animal. (8)

Hypothesis:

Based on these information, the hypothesis was formed that the infection of beehives in Europe with *Varroa constructor* could not be effectively contained with *Chelifer cancroides*, due to its long time of development. *Varroa constructor* appeared in 1977 for the first time and the mite population exploded since then. It is probable that there simply were not enough pseudoscorpions available in order to achieve a biological balance. Furthermore, already in 1977 chemical remedies to fight the varroa mite were tested (9). These chemicals probably also killed the pseudoscorpions and made it impossible to allow a biological control by them. Finally, since the end of the 1970's, modern beehives were favored due to their practicability and their weight so that they replaced traditional wooden beehives and basket beehives almost everywhere up until today. The continuous co-habitation of pseudoscorpions and bees in beehives was made impossible due to smooth walls and missing shelters.

I was fascinated by the idea of fighting the varmints of bees biologically. Therefore, I turned to Prof. Dastych of the University of Hamburg. Mrs. Dastych helped me get a large amount of interesting literature out of an extensive literature collection, with many papers about pseudoscorpions that are not available on the free market. In this collection an article came to my attention that confirmed my previous assumptions. The two-sided paper with the name "The book scorpion, a welcomed guest of bee colonies" (in German: "Der Bücherskorpion, ein willkommener Gast der Bienenvölker") by Max Beier describes that at fault *Chelifer cancroides* lives a rather modest and little reckoned existence inside the beehive (10). This is reasoned by the fact that the book scorpion is able to and likes to easily hide its flat body in finest ridges and gaps inside of wooden beehives, which were used at the time the article was written. Furthermore, the synanthropic life style and the worldwide distribution is mentioned, whereas the natural habitat in warmer regions is tree bark. In colder regions, Chelifer was only able to spread with the help of the human by making use of human housings. Therefore, it is mostly found in stalls, barns, and, as mentioned, beehives. The book scorpion is described as a useful

co-habitant that eats dust mites in old libraries and chases after bed bugs. The book scorpion is also said to have been seen on lousy heads of cattle on which it was hunting for "biting and crawling bugs" (10). Based on the report, *Chelifer cancroides* is respectively important for the fight against varmints inside the beehive:

"The book scorpion even seems to collect bee lice directly from the bees as well as other more or less bothersome invaders. It renders especially useful by hunting the larvae of the dreaded wax mot. (...)There is no damage to this fine use, which the book scorpion could cause, because it is not hurtful to the bees by whom the book scorpion is endured, or to their broods in the honeycombs. (10)"

Especially the ability to delouse mites directly from the bees, as described in the report, is an interesting hint as far as the potential delousing of bees goes that are infested with mites. Should this statement be proven true, consequently, this ability might be transferable and an invaluably important characteristic for the reduction of the varroa mite population, which mostly remains on the bees themselves. I found another hint that refers to these characteristics on the insect gallery homepage. There, it reads:

"Natural enemies of the varroa mite are pseudoscorpions, among these, also the book scorpion. The book scorpions let the bees carry them into the beehive and there they downright collect the varroa mites from the bees (11)."

I asked the author for the literature of this statement, unfortunately he could not recall the source of this information. Potentially, the characteristic of delousing varmints directly from the bees is just a coincidence as soon as *C. cancroides* clings onto the legs of the bees in order to get transported. This behavior, which is known as phoresis, has been observed with many pseudoscorpions (12). It is assumed that phoresis developed due to the capture of prey that is too large. The trigger of phoresis for *C. cancroides* could simply be caused by the feeling of hunger. The described behavior of delousing could be due to the finding of a more suitable prey on the previously taken large animal.