Annex 3

RECORD OF SCIENTIFIC ACHEIVEMENT

Dr Łukasz Przybyłowicz
Institute of Systematics and the Evolution of Animals
Polish Academy of Sciences

Kraków 2019

1. **Name**: **Łukasz Przybyłowicz**

2. **Diplomas and academic degrees, with title of work, and place and year:**

19.11.2003	**Doctor of biological sciences** Institute of Systematics and the Evolution of Animals Polish Academy of Sciences in Kraków Promotor: Prof. Dr Hab. Józef Razowski "Phylogenesis of *Thyretini* (Lepidoptera, Arctiidae and Syntominae) at species level"
11.05.1994	**Master of biology** Faculty of Biology and Earth Sciences Jagiellonian University Promotor: Prof. Dr Hab. Bogusław Petryszak "The weevil (Curculionidae) of Magura Wątkowska in the Lower Beskids"

3. **Information on Earlier Work in Scientific Departments**

May 1994 - present	Institute of Systematics and the Evolution of Animals, Polish Academy of Sciences, Kraków
November 2018 – present	Adjunct
December 2015 – October 2018	Assistant
July 2013 – November 2015	Specialist research technician
November 2010 – June 2013	Specialist technician
March 2004 – October 2010	Adjunct
January 1996 – February 2004	Senior assistant
May 1994 – December 1996	Technician

4. **Achievement being the basis for this application for the award of a post-doctoral degree.**

As an achievement in accordance with Art. 16, Sec. 2 of the Act of 14 March 2003 on Academic Degrees and Academic Titles, and on Degrees and Titles in the Field of Art

(Journal of Laws No. 65, Item 595, as amended), I am indicating a series of five original publications on the subject of:

a) Title of scientific achievement:

"Systematic position and taxonomy of the sub-tribe Thyretina in the sub-family Arctiinae (Lepidoptera: Noctuoidea)"

b) Papers forming part of this scientific achievement. Impact factor (IF) shown according to year of publication (for publications from 2019, IF from 2017). MNiSW points cover the harmonised list of scientific journals for the years 2013-2016.

H1) Przybyłowicz Ł. 2009. Thyretini of Africa. An Illustrated Catalogue of the Thyretini (Lepidoptera: Arctiidae: Syntominae) of the Afrotropical Region: Entomonograph Series vol. 16. Apollo Books. Denmark, 170 pp.

[MNiSW pts = **25**]

H2) Przybyłowicz Ł. 2013. Review of subgenus *Compsochromia* Kiriakoff, 1953 (Lepidoptera: Erebidae: Arctiinae, genus *Balacra*) with identification keys and description of a new species from Cameroon. Annales de la Société Entomologique de France 49(1): 53-60.

[IF_{2013} = **0.539**; $IF_{5\text{-year}}$ =**0.626**; MNiSW pts = **20**]

H3) Przybyłowicz Ł., Tarcz S. 2015. Strong sexual dimorphism unraveled by DNA analysis – towards a better understanding of *Pseudothyretes* classification (Lepidoptera: Erebidae: Arctiinae). Zoological Journal of the Linnean Society 173(1): 22-54.

[IF_{2015} = **2.316**; $IF_{5\text{-year}}$ =**2.717**; MNiSW pts = 4**0**]

H4) Przybyłowicz Ł., Ochse M. 2017. A New, Peculiar Genus and Species of Thyretina (Erebidae: Arctiinae, Syntomini) and a Review of African Syntomini Bearing a Pointed Abdominal Tuft. Annals of the Entomological Society of America 110(1): 104-112.

[IF_{2017} = **1.558**; $IF_{5\text{-year}}$ =**1.308**; MNiSW pts = 3**0**]

H5) Przybyłowicz Ł., Lees D.C., Zenker M.M., Wahlberg N. 2019. Molecular systematics of the arctiine tribe Syntomini (Lepidoptera, Erebidae). Systematic Entomology. https://doi.org/10.1111/syen.12343

[IF_{2017} = **4.237**; $IF_{5\text{-year}}$ =**3.560**; MNiSW pts = **35**]

Total *Impact Factor* according to year of publication: **8.650**

Total five-year *Impact Factor* for indicated achievement: **8.211**

Total MNiSW points: **150**

Declarations by all co-authors, specifying the individual contribution of each of them to the preparation of the works constituting the above-mentioned scientific achievement, can be found in Annex 5.

c) Discussion of the scientific goals of the work, the results achieved, and their potential application

Butterflies (lepidoptera) are among the most numerous of insects. So far, about 160 000 species have been described. Among the 47 super-families (Kristensen et al. 2007), Noctuoidea (Owlet) is one of the youngest and most numerous butterfly groups (van Nieukerkan et al. 2011). Although consisting of mostly large and medium-sized species, thus making it relatively easy to study morphologically, the super-family's systematics are still unclear compared to many other butterfly groups. Until the 1980s, the division into four families was commonly accepted: Prominent (Notodontidae), Tussock (Lymantriidae), Tiger (Arctiidae) and Owlet (Noctuidae). Genetic research initially based only on a single mitochondrial gene (cytochrome oxidase c sub-unit 1, COI) proved that such a division is completely artificial and based on erroneous assumption that clear autapomorphs of both Tussocks and Tigers indicate that they are equivalent to the Prominents and Owlets in terms of rank in the phylogenetic system Noctuoidea (Mitchell et al. 2006). Subsequent analysis of different systematic groups conducted on the basis of a larger number of genes indicated that both Tigers and Tussocks should be treated as closely related sub-families within the newly formed Erebidae family, which also includes some of the former Noctuidae. Although the monophyleticity of Arctiinae was later confirmed many times on the basis of both

morphological and molecular research, the internal division of the group of over 11 000 species still raises a lot of controversy. Traditionally, they are divided into three tribes (formerly sub-families): Lithosiini, Arctiini and Syntomini (Jacobson & Weller 2002). The first two groups are quite well defined, unlike Syntomini. There are no modern comparative studies based on both the analysis of morphological and genetic features, as Syntomini have always remained off the beaten track of researchers' interests. In addition to Syntomini, included in the Thyretina sub-tribe is a group of African butterflies previously classified as part of the Notodontidae, also a completely separate family (Kitching & Rawlins 1999).

The scientific goals of the presented habilitation achievement are:

- To test the hypothesis concerning the monophyleticity of the Thyretina sub-tribe and its position within the Syntomini tribe
- To explain the relationships within the Thyretina sub-tribe
- To revise the systematics of the Thyretina sub-tribe
- To revise the taxonomic units within the Thyretina sub-tribe

The presented research problems were developed in a series of five publications. The first of these is the book (**H1**), of which I am the sole author. This is an extended catalogue of species, containing many elements typical for taxonomic revision and monographic study. The publication is based entirely on newly developed or personally revised materials, rather than being a compilation of literature data. The next three papers (**H2, H3 and H4**) contain the results of systematic and taxonomic studies of the most problematic types or groups of species, based on analysis of both morphological and molecular data. The summary of the research (**H5**) is to clarify the status of the Thyretina sub-tribe within Syntomini, based on genetic diversity and evolutionary and biogeographic analysis for the entire Arctiinae sub-family.

Among the basic problems associated with establishing the phylogenetic relationships of the studied butterflies and their evolutionary history are the correct determination of the systematic placement of all species, and grouping them according to kinship. The most commonly available research materials are only dry museum specimens, which allow analysis of morphological features, on the basis of which presumptions about supposed relationships

may be drawn. During almost 200 years of taxonomic research, various methods were used, and researchers have interpreted observed differences subjectively. The concepts of species and other nomenclature categories have also changed. This led to the creation of several hundred species-level names defining various taxa, whose actual rank and similarities were difficult or even impossible to determine without a re-examination of descriptive types (Kiriakoff 1960). In the course of research and analysis of museum material, I conducted a comprehensive review of the entire Thyretina sub-tribe (**H1**). The basis of the proposed taxonomic-systematic solutions and decisions on nomenclature was detailed analysis of descriptive types of 332 taxa of species rank (including all other descriptions, regardless of their nomenclature value such as aberrations, forms or "varieties"). As a result of comparative morphological studies, I considered 194 as important species and 138 as synonyms. I grouped species in 21 types along with 19 synonyms. For each species in the catalogue part, I provided bibliographic information about the original description, cited the “type locality”, and verified the number of specimens in a typical series. For the first time, as many as 62 species rank taxa and seven generic category names were considered synonyms of previously described taxa.

The analytical part consisted in checking the literature containing all original descriptions, and morphological studies of descriptive types. To this end, I engaged in study visits (lasting a few months in total) to more than a dozen European museums, including collections in London, Tervuren, Berlin, Paris, Copenhagen, Vienna, Stockholm and several other smaller locations. I examined the descriptive types of all taxa, except for a few specimens deposited at the museum in Bulawayo (Zimbabwe), which are the models for the species described by Kiriakoff (1973). First, I verified the compatibility of museum specimens labelled as types with information contained in the published descriptions. In each case, I carried out detailed morphological analysis of external features including colouration and pattern. I thoroughly examined the reproductive apparatus, in particular the construction of aedeagus and vesica (shape, number and arrangement of cornuti), which in many cases are the key diagnostic features that differentiate the species. The result of my research was the unified division of the tribe for the first time into cohesive taxonomic units (types), grouping separate taxa at species level with correct synonyms. As a result of the research, four types were transferred to other systematic units. I placed *Meganaclia* Aurivillius, 1892 and *Nacliode*s Strand, 1912, in the Arctiinae sub-family due to the absence of abdominal pheromone glands in females. Such

glands, located dorso-laterally to the rectum (Bendib & Minet 1998), are very clear synapomorphy of all representatives of Thyretina. At the same time, representatives of both types have distinctive tymbal organs on the lateral surface of the abdomen, which are not present in representatives of Syntomina. *Pseudodiptera* Kaye, 1918, and *Thyrogonia* Hampson, 1898, I considered representatives of Syntomina - a sister group to Thyretina. These species do not have either tymbal organs or pheromone glands (females). Together with the four above types, I separated 11 species included in them from Thyretina (**H1**).

I proposed (**H1**) the first significant systematic changes in relation to several type units based on detailed morphological studies:

1) *Automolis* Hubner, [1819] - previously treated as a synonym for the genus *Metarctia* Walker, 1855, I elevated this to a new genus based on newly discovered, unique and highly characteristic features of the typical species *A. meteus* (Stoll, 1781). I considered its autapomorphies to be: a) the presence of prominent, acute appendages on the tympanum, b) short and well-built tibia of the first pair of legs with a prominent extended epidermis and prolonged epiphysis, c) rounded valva without spines, and d) short and wide aedeagus. The genus is limited to southern Africa and the mountains of Kenya and Tanzania.

2) *Balacra* Walker, 1856 - the second Thyretina genus by number of species. I revised its internal division based on an incorrect interpretation of *B. preussi* and *B. caeruleifascia* described on the basis of females. Despite the external similarity, I detected small but consistent features of the pattern and colouring of the abdomen and front wings allowing for correct adjustment in regard to the males. This enabled a true interpretation of sub-genuses of these species. In addition, I proposed one subjective synonym treating *Balacrella* Kiriakoff, 1957, as a synonym of *Daphaenisca* Kiriakoff, 1953. Both sub-genuses are represented by individual species difficult to distinguish based on external features. Differences in the structure of the male reproductive organs regarding minor details of the uncus and aedeagus cannot be regarded as generic. As a result (**H1**), I suggested dividing the *Balacra* into seven sub-genera easily distinguishable both on the basis of the characteristics of the habitus and the construction of the male reproductive organs (mainly the uncus).

3) *Cameroonia* Przybyłowicz, 2009 - not previously distinguished from the *Metarctia* genus. I proposed a new genus category for the species *Metarctia nigriceps* Aurivillius, 1904, with taxa clearly different from all other representatives of the genus *Metarctia*, and which cannot

be included in any of the other types described to date. The apomorphic features are feathery antennae of the male and female, and the specific structure of the reproductive apparatus of both sexes. I described and categorised this genus in detail.

4) *Oenarctia* Kiriakoff, 1953 – one of the sub-genera of *Metarctia* Walker, 1855, which I synonymised with the nominative sub-family. Comparison of the morphological structure of taxa included in both *Metarctia* and *Oenarctia* pointed to the inconsistency of features distinguishing sub-genera, their occurrence within particular sub-genera, and the existence of species with intermediate traits. As a result, I found it unreasonable to pinpoint a further, hard to define systematic unit.

5) *Rhipidarctia* Kiriakoff, 1953 - detailed morphological analysis of *Takwa* Kiriakoff, 1957, and *Elsita* Kiriakoff, 1953, indicated that they correspond to the genus *Rhipidarctia*, very clearly characterised by the presence of specific traits in the male reproductive organs (the presence of "pseudovalva") and females (unscaled area of the opening of the copulatory duct on the abdominal sternum). All species included in *Takwa* and *Elsita* have such features while lacking other unique diagnostic features.

To sum up, the book (**H1**) is unique, the first such modern development of the Thyretina sub-tribe (formerly the Thyretina tribe), based entirely on original morphological research and a critical study of the literature. All data are the result of my research, and the literature information (quotations, descriptions and diagnoses) has been carefully verified based on the original sources.

The study contains 194 original illustrations, mostly representing typical specimens (mainly holotypes). Only in a few cases (no type available, those available being in very poor condition, or due to the need to illustrate the opposite sex) have other specimens been illustrated.

I was the first to illustrate the morphological structure of male reproductive apparatus (for 108 species) and females (76 species). The incompleteness of illustrations is mainly due to the lack of description of the appropriate sex in the case of many taxa, or to the uniqueness of holotypes (for species with colour features on the abdomen, as in the case of *Balacra* and *Bergeria*).

The presented results explained a lot of controversy regarding the taxonomy of the Thyretina sub-tribe. At the same time, they indicated the most important problems and issues that remained unexplained. One of them was the lack of comparative materials, particularly important in the case of taxa with very similar morphology. In many cases, comparison of the holotypes of two or more taxa did not allow an unambiguous conclusion to be drawn on whether they represent the same or close, but different species. The observed differences concerned such minor details that they did not allow unambiguous classification of intra or inter-species variability. In such cases, it is necessary to thoroughly review controversial genus and species groups based on a large, indeed extended, amount of comparative material covering both sexes. Another research problem indicated by this research was the detection of a number of new taxa, which should be described in accordance with the standards of the International Code of Zoological Nomenclature (ICZN). Three subsequent publications (**H2, H3 and H4**) constituting the habilitation achievement, are devoted to this issue.

The subgenus *Comprochromia* Kiriakoff, 1953, currently covering three species, is an example of a group in need of taxonomic revision (**H2**). Interestingly, it includes very characteristic taxa with very unusual structure: significant body size, almost completely transparent wings, disproportionate wing sizes (front large, rear significantly smaller), and significant abdominal size. Until the revision, this sub-family included two important species, *Balacra* (*Compsochromia*) *compsa* (Jordan, 1904) and *B.* (*C.*) *diaphana* (Kiriakoff, 1957) and four other taxa of undetermined status (Vari et al. 2002). The first species is quite often found, while the second's individuality was questionable due to the fact that it was known only from one pair (male and female) and is morphologically very similar to the previous. My detailed analysis of descriptive types and new material confirmed the distinctiveness of both taxa on the basis of small but distinct morphological features, and made it possible to determine their synonyms. I described and illustrated for the first time the characteristics of the male and female reproductive apparatus, as well as external features (the colour pattern of the front wing). Querying museum collections in London and Copenhagen led to the detection of a third, clearly distinct taxon *Compsochromia*, which I described as *Balacra* (*C.*) *flava* Przybyłowicz, 2013. This species was described in detail, clearly highlighting the diagnostic features that distinguish it from the other two. For all three species, I created for the first time the keys that enable correct identification using both external features and the morphological

structure of the male reproductive apparatus. I illustrated every proposed feature in detail, to facilitate correct interpretation. The newly described species is endemic to the mountain of Cameroon (an extinct volcano), which is further proof of the unique importance of this massif in the preservation of the biodiversity of the African continent.

Pseudothyretes Dufrane, 1945, though not the most numerous among Thyretina was at the time of testing one of the most difficult in terms of taxonomy (Kiriakoff 1953, 1959, 1961). None of the seven species described were known from both sexes, although males and females are often caught and represented in collections around the world. Most taxa were known only from males, and only *P. carnea* (Hampson, 1898) and *P. mariae* Dufrane, 1945, were described on the basis of females. The reasons for this were exceptional sexual dimorphism (females being much larger than males) and the significant uniformity of colouration and patterning of both males and females. In addition, no original description contained information on the construction of reproductive apparatus. Therefore, comparative material in the collections remained unmarked, or was usually designated as “most common" *P. perpusilla* (Walker, 1856). A detailed revision of the group was necessary. This, for the first time, indicated the correct interpretation of already known taxa, and led to the detection of two species previously unknown to science (**H3**). The gathering of more than 750 specimens enabled much more accurate analysis of features based on both morphology and genetic research. Comparison of variation of the mitochondrial gene fragment encoding cytochrome oxidase c sub-unit 1, COI, enabled matching of the female appropriate for the two species (*P. kamitugensis* Dufrane, 1945, and *P. perpusilla*), previously known only from males. The same procedure allowed the unambiguous demonstration that *P. rubicundula* (Strand, 1912), described on the basis of the male, is the same as *P. carnea*, the description of which was based on a single female. A detailed discussion of all other premises (colouring, front wing pattern and type locality) confirming the results of genetic analysis for these two taxa was also carried out. Morphological analysis of the construction of the male reproductive apparatus led to discovery of two further previously unknown species (*P. mirus* Przybyłowicz, 2015, and *P. obscurus* Przybyłowicz, 2015), which was confirmed both by the distinctiveness based on characteristics (mainly the pattern on the wings) and genetic variation.

I was also first to develop two separate keys allowing identification of all species of the genus based on the external and reproductive organ characteristics of males. Molecular analysis of 61 individuals representing all seven species made it possible for the first time to determine the genetic diversity at the intra and inter-species level.

From the nomenclature and taxonomic point of view, it is also important to note that the work contains a comprehensive summary of all existing published data on the subject of the study group, along with appropriate interpretation. Detailed descriptions of each species concerning re-catergorisation are based only on verified specimen markings. For representatives of the genus *Pseudothyretes*, I provided the first description and illustration of the structure of the reproductive apparatus of females, along with morphological details of labial palpi (scanning photography) and an indication of diagnostic features.

The accumulation of additional material led to the discovery of *Tervurenia eloumdeni* Przybyłowicz & Ochse, 2017, another species previously unknown to science. Preliminary morphological research revealed this to be so distinct from the previously known representatives of the sub-tribe that the new, so far monotypic genus *Tervurenia* Przybyłowicz & Ochse, 2017, was proposed for it (**H4**). Representative specimens were detected independently by both co-authors. A special combination of simultaneously occurring features indicating the separateness of the genus (autapomorphs) include feathery antennae, the presence of an elongated group of scales at the end of the abdomen, a flattened uncus with wide split at the end, and a short, simple aedeagus with numerous, prominent cornuti. The species' distinction and kinship of the newly described taxon were analysed and confirmed using the mitochondrial gene (COI).

The presence of a group of elongated scales at the end of the abdomen is a unique feature among butterflies, and occurs more often in females than in males. I discussed this issue in detail in the publication. Until now, this occurrence has been observed in representatives of several unrelated families of butterflies (for example, Lycaenidae, Tortricidae and Notodontidae). This means that it has evolved several times and independently, and its role is associated in the case of females with the process of creation and protection of eggs against predators and parasites (Floater, 1998). The differentiation and function of this organ in

males is much less well understood. Typically, the group of scales is not much longer than the other scales covering the abdomen. Only a few representatives of Clearwing (Sesiidae) and Tiger display a clearly elongated "tail". In the latter group, this occurs almost exclusively among Thyretina (*Lempkeella* Kiriakoff, 1953; *Daphaenisca* Kiriakoff, 1953; *Melisa* Walker, 1854; *Melisoides* Kiriakoff, 1953, and the newly described *Tervurenia*). The function of this organ in males remains unknown. My work is the first to indicate that it is probably an important element that protects butterflies from predators. I noticed that all species with this "tail" are brightly coloured, and that the colour pattern (light and dark transverse stripes on the abdomen and sternum, with uniformly dark, often shimmering front wings) imitates some species of *Hymenoptera*. The body structure, and in particular the strongly developed sternum in comparison with the size of the abdomen and the extremely reduced posterior wings may suggest a flight manner similar to the largest *Hemipepsis* Dahlbom, 1844, specialised in spider hunting. However, this hypothesis is currently difficult to verify due to the poor knowledge of behaviour (flight method, daily vs. nocturnal activity) of species possessing the organ in question.

The gradual accumulation of information on the morphological differences between the various members of the Thyretina sub-tribe, as well as the growing stock of fresh material useful for genetic analysis collected during field trials in Uganda, Namibia and South Africa, prompted me to ask more general questions: a) Do Thyretina present a monophyletic group? b) What are the phylogenetic relationships of Thyretina in relation to the other groups within Arctiinae, in particular to those considered to be the sister group Syntomina? c) What was the evolution of the tribe and which types are related? d) Are the genetic data consistent with the results of morphological research?

An attempt to answer the research problems presented above is included in a summary of the habilitation thesis published in "Systematic Entomology". The scope of the research has been extended to cover the entire Syntomini tribe. Analysis of the results was carried out, taking into account the extensive comparative material covering the remaining currently distinguished Tiger tribes (Arctiinae: Arctiini, Lithosiini), and bearing in mind the recently separated *Amerilini* (Dubatolov, 2010) in order to interpret the detected phylogenetic relationships in an even broader context.

Thyretina, together with the sister sub-tribe Syntromina, constitute the most "neglected" taxonomic and systematic tiger group. So far, there have been no synthetic morphogenetic studies. Among the genetic work, only a few Thyretina and Syntomina taxa have been included in phylogenetic analysis, including the Arctiinae sub-family. Within Thyretina, these were only individual species from *Hippurarctia* (Zaspel et al. 2014) and *Balacra* (Regier et al. 2017). The aim of the research was to understand the diversity and mutual relations within the Syntomini tribe, with particular emphasis on Thyretina. For the first time, eight genes were sequenced for 91 species representing 39 genera of Syntomini (including 16 from Thyretina). Most known genera and all major geographic regions outside of Australia were analysed, including abundant material from Madagascar. The most important, albeit somewhat surprising result, was the proof that Thyretina is not actually a monophyletic group in the traditional manner, as presented in my book published in 2009. *Thyretes* Boisduval, 1847, and *Pseudothyretes* previously categorised within the tribe create a phylogenetic line separate from other close Thyretina relatives from Madagascar. In addition, they are distinguished by a distinct synapomorphia: probably, independently of *Amata*, they lost the retinaculum in the mechanism connecting the front and rear wings.

My analysis indicates that both (*Thyretes*, *Pseudothyretes*) are more closely related to the traditionally distinguished Syntomini sub-tribe than the other Thyretina. Consequently, they question the usefulness of maintaining Thyretina as an important systematic unit. In the light of the results obtained, two nomenclature solutions were possible. Either Syntomini should be formally divided into five sub-tribes reflecting monophyletic groups, or the Thyretina sub-tribe should cease to be formally divided in favour of the Syntomini tribe system without formal division of Syntomini and Thyretina at lower rank. We proposed the second solution, arguing that the creation of new formal units (in the nomenclature sense) would not bring significant benefits to the system, Syntominia would only introduce names that would have to be included in each subsequent revision. Thyretina was formally proposed as a synonym for the Syntomini tribe. The sub-genera *Thyretarctia* (in *Metarctia*) and *Daphaenisca* and *Callobalacra* (in *Balacra*) proved to be so distinct (morphologically and genetically) from the other representatives of *Metarctia* and *Balacra* that I elevated them to the rank of genus. Thanks to this, *Metarctia* and *Balacra* now form well-defined monophyletic groups, which is confirmed by genetic and morphological studies.

Most important cognitive value of this habilitation achievement:

1) Arranging the systematics of the group at the generic and species level through detailed morphogenetic analysis:

- creating a catalogue of all described species;
- synonymising seven genera;
- raising three sub-genera to the rank of independent genera;
- proposing one new name on the genus level;
- formally synonymising 63 species;
- describing four new species;
- isolating four genuses of the thyretina sub-tribe together with 11 species within, and transferring them to other systematic units.

2) Proposing a new group systematic order in relations to other tribes of the Arctiinae sub-family based on morphogenetic features:

- explaining the affinities between genera and, consequently, recognising Thyretina as a paraphyletic group;
- describing the Thretina sub-tribe into two non-related phylogenetic groups and proposing the formal end to treating it as a separate taxonomic group;
- presenting the innovative division of Syntomini into clades without formal division into Syntomini and Thyretina sub-tribes.

3) Developing tools for taxonomic verification of museum material and new specimens caught in the field:

- keys for identifying selected species on the basis of external features and the morphology of male and female sexual reproductive apparatus;
- illustrations of all species, and of the male and female reproductive apparatus representing in excess of 60% and 40% of known species, respectively.

4) Ordering in terms of nomenclature, which will facilitate future revision and monographic research:

- verifying trapping locations (the locus typicus, or type locality) of all 332 described species-level names;
- verifying the number and status of specimens typical of all described species-level names, and determining lectotypes in a number of cases.

Literature

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5. Discussion of scientific activity and other scientific and research achievements

I am a graduate of the Faculty of Biology and Earth Sciences at the Jagiellonian University. My studies played an important role in developing and shaping my interest in entomology. From the very beginning, I was an active member of the Student Naturalist Circle at the Jagiellonian University, taking part in various field studies carried out by Jagiellonian University staff. My master's thesis entitled: " The weevil (Curculionidae) of Magura Wątkowska in the Lower Beskids" was carried out under the supervision of Prof. Dr Hab. Bogusław Petryszak, and defended in 1994. After graduation, I pursued a scientific career which I have been continuing at the Institute of Systematics and the Evolution of Animals of the Polish Academy of Sciences (ISEA PAS) in Kraków. In 2003, I defended my doctoral dissertation at ISEA PAS under the title **"Phylogenesis of Thyretini (Lepidoptera, Arctiidae, Syntominae) at the genus level".**

The two main aspects of my scientific research can be described as a) systematics, taxonomy and biogeography of Arctiinae and b) the distribution, biology and ecology of Polish butterflies.

a) Systematics, taxonomy and biogeography of Arctiinae

Africa is the continent on which Arctiinae are known the poorest. This is clearly visible when analysing the quantity and quality of publications from the past half century about Arctiinae on this continent. These are mostly short works containing descriptions of individual species. The exceptions are wider studies, most of which are still limited to the southern regions of the continent (Vari et al. 2002, Krüger 2015). This situation prompted me to undertake long-term studies on the systematics and biogeography of African Arctiinae. The first publication, a revision of the genus *Melisoides* Strand, was published even before I obtained my doctoral degree (**P22**). Subsequent works were published successively as a result of the development of museum material representing *Balacra* Walker, 1856 (**P08**), *Metamicroptera* Hulstaert, 1923 (**P26**) and *Melanonaclia* Griveaud, 1964 (**P27**), specimens collected during a research trip to Uganda (**P38**), and as a result of cooperation with lepidopterologists from Germany (**P30**) and Poland (**P01**). Issues related to the phylogeny of Thyretina sub-tribes (formerly the Thyretina tribe) were the subject of my doctoral dissertation. The obtained results indicated the urgent need to broaden research with detailed systematic and taxonomic studies based on extensive research material. The post-doctoral work presented for evaluation is the result of this continued research. My studies of Arctiinae of the African continent continue and constitute the main stream of my scientific research.

At the same time, I was researching the butterflies of the Korean Peninsula. The inspiration for this was the very rich and unique collection of butterflies from North Korea which form part of the ISEA PAS lepidopterological collection. They became the basis for cooperation with South Korean lepidopterologists (Prof. Kyu Tek-Park, Bong-Kyu Byun). In the initial stage of our cooperation, we focused on the development of *Lithosiini* and *Arctiini*. Determining several dozen specimens led to the first detection of two species – *Atolmis rubricollis* (Linnaeus, 1758) and *Arctia flavia* (Fuessly, 1779) – from the Korean Peninsula, and three further species (*Diacrisia irene* Butler, 1881, *Hyphoraia aulica* (Linnaeus, 1758) and *Arctia plantaginis* (Linnaeus, 1758)) from the territory of North Korea (**P19**). For all species, I prepared illustrations of sexual reproductive apparatus, as well as distribution and host data. For Syntomini, a taxonomic overview of all species from the Korean Peninsula was prepared (**P05**). Three species belonging to the genus *Amata* Fabricius, 1807, were discussed,

of which *A. sperbius* (Fabricius, 1787) was first noted. Descriptions of all species contain a re-description of male and female reproductive apparatus. We described the female reproductive organs for the first time. A detailed map of the distribution of all taxa in the area of the peninsula was presented. I constructed three innovative separate keys for marking species based on the external appearance and male and female sexual reproductive apparatus. In the discussion I presented arguments confirming the occurrence of *A. sperbius* in North Korea, at a considerable distance from its next nearest locations (Bhutan and the north of India). My research on the fauna of south-east Asia has been summarised in a richly illustrated book of more than 440 pages, entitled "Moths of North Korea", of which I am a co-author (**P16**).

Another stream of my research interests is the systematics of Arctiinae in the neo-tropical region. I carried out projects on this subject mainly before obtaining my doctoral degree. In the first publication, I re-described *Macrocneme imbellis* Dietz, 1994 (**P13**). The new material made it possible to significantly broaden the range of known species from Iquitos (Peru), and to discover a previously unknown colour form. The next two works were devoted to *Tipulodes* Boisduval, 1832. I was the first to carry out meticulous taxonomic analysis of the genus (**P17**). *Tipulodes* was redefined, based on analysis of morphological characteristics of imago and a re-description of both species included in the genus by verification of holotypes and additional material from 15 museums, including 150 specimens. This made it possible to show the exact distribution of the genus on the South American continent. In addition, I described the new, very characteristic species *T. annae* Przybyłowicz, 2003, known thus far from northern Colombia (**P21**). Continuing this research trend, I participated in a project concerning the systematics and origin of the Arctiinae sub-family in the neo-tropical region (**P06**). One of the most intriguing results of molecular analysis in this respect was the indication that the neo-tropical Arctiinae originate from the Old World, and their colonisation of South America took place as a result of at least six independent migrations. At the same time, the results obtained indicate that numerous monophyletic groups derived from subsequent radiation already taking place on the South American continent.

My interest in the distribution and dynamics of butterfly ranges on the European continent, with particular emphasis on Arctiinae, was reflected in my participation in the project Fauna

Europaea (2000-2004), in which I was responsible for the preparation of data (both fauna-related and systematic) of the Arctiinae sub-family. At the initial stage of the work, I verified the systematic sub-families, species belonging to genera, synonyms at the genus level, as well as nomenclature data (authorship and year of description). I obtained all this information by analysing the original descriptions and the latest taxonomic works. In the next stage, I prepared a matrix of data on the occurrence of individual species on the European continent, along with links to the published source data. In the following years, I updated and verified all information. Currently, this information is available at https://fauna-eu.org. This research resulted two publications. In the first of these, I noted the first presence of *Eilem marcida* (Mann, 1859) in Malta (**P34**). This species had been incorrectly marked and mentioned in the islands as *E. pygmaeola pallifrons* (Zeller, 1847). The verification of the comparative material made it possible to confirm indisputably the presence of *E. marcida* in Malta. Importantly, it was also possible to detect and illustrate additional, previously unknown features confirming the distinctiveness of both taxa. I also discussed in detail the intra-species variability of *E. marcida* and the relationship with a twin species *E. caniola* (Hübner, 1808). Another result of these studies was the very interesting work on the invasive Lepidoptera species recorded in Europe as a result of globalisation, on an anthropogenic basis (**P31**). There were as many as 97 such taxa, of which more than a third belong to the *Pyraloidea* super-family, and up to 30% of all species come from Asia. Most of all the invasive species are limited to man-made habitats, and more than 50% are found only in parks and gardens.

b) The distribution, biology and ecology of Polish butterflies

This is the second important aspect of my scientific research. I am the author or co-author of a series of comprehensive studies of butterfly fauna in a number of protected areas in southern Poland: Gorce (**P11**, **P12** and **P39**), Babia Góra (**P23**), Bieszczady (**P20**), and Ojcowski National Park (**P29**). I also took part in the preparation of information on butterflies for the purpose of drawing up plans for the protection of national parks located in these areas. I was the coordinator of "invertebrates" in Gorczański National Park. The distribution and genesis of the endangered species of the day butterfly Anomalous Blue *Polyommatus ripartii* (Freyer, 1830) in Poland (**P14**) was of particular interest to me. I researched this issue in 2009-2011 as the head of an NCN grant project, which resulted in two publications (**P02** and **P03**). As

a specialist in the Arctiinae sub-family, I took part in the preparation of the latest list of butterflies in Poland (**P37**), as well as relevant studies for six species for the "Polish Red Book of Animals" (**P24**). I am also the national coordinator in regard to the Jersey Tiger butterfly (*Euplagia quadripunctaria* Poda, 1761) and the author of original monitoring recommendations for this species (**P32**). My own observations and cooperation with Polish lepidopterologists led to the creation of several contributing works (**P15**, **P18**, **P35** and **P36**), and to summaries of knowledge about day butterflies of the super-family *Papilionoidea* in Kraków, in terms of qualitative changes occurring over decades (**P25**).

c) Other research interests

Although my main research interests are focused on the systematics and taxonomy of butterflies, some other interesting research projects carried out over the past few years concern a broad spectrum of ecological issues. This began with work on the possibility of semi-automatic recognition of one of the very important pests of corn cultivation, the European Corn Borer (*Ostrinia nubilalis* Hübner, 1796) (**P04**). During this research, I tested the usability of personal computers equipped with appropriate software to distinguish this from the other most common pests found on corn plantations. Accurate and timely determination of the pest's presence is crucial for the implementation of an appropriate and effective biological method of eradication. In my work, I showed experimentally that 97% of the 247 specimens belonging to four butterfly species, being correctly marked, which was confirmed by morphological analysis of each specimen examined. The obtained results indicated that the technique based on morphometric measurements of the front wing can be a useful tool for monitoring the corn borer. This method can be used by farmers to identify the pest and start its eradication at the optimal time.

Another project concerned the testing of the hypothesis that flood embankments are among the important refuges of herbivorous invertebrate biodiversity in urban areas. The test group consisted of day butterflies from the *Papilionoidea* super-family. During the research, I also pointed out the main factors affecting the species richness and abundance of these insects. The research demonstrated, for the first time, the unique importance of such embankments and the plant communities covering them for the maintenance of the biological diversity of flora and

butterflies in urban areas. At the same time, I highlighted the negative effect of intensive mowing on maintaining such an important function of these embankments (**P07**).

A slightly different aspect of ecological dependencies is the issue of changes in the characteristics of lepidopterofauna (measured by species richness, abundance and characteristics of clusters) in relation to altitude and seasonality. This intriguing question has been insufficiently studied in the tropical zone, and the existing works concern only selected butterfly families, a short study period or low numbers for sampling. Participation in an international project coordinated by Dr. Robert Tropek (Czech Acedemy of Sciences, Czech Republic) enabled me to carry out the first extensive research on the extinct volcano of Cameroon, on a transect with an elevation gradient of 300 to 2,400 m above sea level. In this project, I was responsible for identifying 3 645 Arctiinae specimens, which comprised one of the six butterfly groups studied. Eventually, I divided them into 86 morphs (three quarters marked by species). I also prepared a database containing information on the date and method of capture, altitude and position number, which was used to construct a uniform matrix allowing ecological relationships to be determined. The results of the research indicate the maximum biodiversity of Lepidoptera in the middle of the dry season although for Arctiinae and Saturniidae it was highest during the transition period between the dry and rainy seasons. There was also a significant change in the species composition of Arctiinae and fruit feeding moths between the seasons, as well as quite specific seasonal specialisation of certain species sets. Qualitative and quantitative changes recognised for the first time as a result of this research prove considerable sensitivity to the expected global climate change. Butterflies in all developmental stages play a key role as first-order consumers, pollinators and food of predators, which is why the detected cyclical seasonal changes can significantly affect the dynamics of entire ecosystems (**P09**).

Completely outside the main stream of my interests regarding native lepidopterofauna are observations about the occurrence of species of insects belonging to other systematic groups, which are of interest to me for various reasons. These observations were published as short reports. During my studies, and afterwards, I did not limit my interests to butterflies alone, thanks to which I was able to detect a number of other species that were either rare or new to Polish fauna. This included information on the first confirmation of the presence in Poland of

Chrysura trimaculata (Förster, 1853) from the order of Hymenoptera (**P10**) and *Bittacus hageni* Brauer, 1860 belonging to the order of Mecoptera (**P28**). Concerning the aphid *Rhopalosiphum nymphaeae* (Linnaeus, 1761), I detected in Poland a new species of host plant, the Floating Aquatic Fern *Salvinia natans* (Linnaeus, 1753) (**P33**). Reports on Hymenoptera and Orthoptera are being prepared as co-authored works.

d) Plans for the future

In the next three years, I plan to concentrate on research into Syntomini (Madagascar), as part of an international project of which I am head, launched this year and funded by the National Science Centre. There will be both taxonomic and evolutionary-phylogeographic research. In a three-person research team, we will try to explain the role of Madagascar endemics in shaping the biodiversity of the African continent, and the potential migration routes for species re-colonising Africa. The project is based on both morphological and genetic analysis. At the same time, other, smaller projects will be continued for selected types of African Arctiinae such as *Mecistorhabdia* Kiriakoff, 1953, and the group "*Spilosoma*" *bifurca* (Walker, 1855). National fauna research will focus on statistical elaboration of ecological data collected during the inventory of daylilies of the Nowotarska Basin bog, and on phylogeographic and dispersal dynamics of Arctiinae Jersey Tiger, also including European populations.

My other scientific and didactic achievements are presented in the "List of published scientific papers and information on didactic achievements, scientific cooperation and popularisation of science", constituting Annex 6.

Kraków, 25.02.2019 Łukasz Przybyłowicz