

Appendix 3

Summary of scientific accomplishments dr Wojciech Solarz

Institute of Nature Conservation

Polish Academy of Sciences

Kraków 2019

1. Name and surname

Wojciech Solarz

2. Diplomas, degrees – the name, place and year of their acquisition and the title of the PhD dissertation

1995 – Master’s degree in biology

Faculty of Biology and Earth Sciences, Jagiellonian University, Kraków

Master’s thesis: „Awifauna lęgowa kamieniołomów kielecczyzny” („Breeding avifauna of quarries in the Kielce region”)

Supervisor: dr hab. Jacek Wasilewski

2003 – PhD of biological sciences, specialisation: biology

Institute of Nature Conservation, Polish Academy of Sciences, Kraków

PhD thesis: „Demografia i behavior w populacji rokitniczki *Acrocephalus schoenobaenus* L. w dolinie Nidy” („Demography and behaviour in the sedge warbler *Acrocephalus schoenobaenus* L. population in the Nida valley”)

Supervisor: prof. dr hab. Zbigniew Witkowski

3. Information on previous employment in scientific units

Since 1.09.1999 r. – Institute of Nature Conservation, Polish academy of Sciences, Kraków

4. Scientific accomplishment according to the article 16 paragraph 2 of the Act of 14 March 2003 on Academic Degrees and Titles and on Degrees and Title in Art (Journal of Laws No. 65, item 595, as amended)

a) Title of the scientific accomplishment:

As accomplishment, in accordance with Art. 16 paragraph 2 of the Act of 14 March 2003. On Academic Degrees and Titles and on Degrees and Title in Art (Journal of Laws No. 65, item 595, as amended.), I indicate a series of six original papers entitled:


**Alienness and invasiveness of species –
analysis of key problems in biological invasion science**

b) The publications included in the scientific achievement


corresponding author

H1. Wilk-Woźniak E., **Solarz W.**, Najberek K., Pocięcha A. 2016. Alien cyanobacteria: an unsolved part of the “expansion and evolution” jigsaw puzzle? *Hydrobiologia* 764, 65-79.


[IF₂₀₁₆: 2,056; IF_{5-year}: 2,447; MNiSW: 30]

H2. Pocięcha A., **Solarz W.** , Najberek K, Wilk-Woźniak E. 2016. Native, alien, cosmopolitan, or cryptogenic? A framework for clarifying the origin status of rotifers. *Aquatic Biology* 24: 141–149.

[IF₂₀₁₆: 1,600; IF_{5-year}: 1,645; MNiSW: 25]

H3. **Solarz W.** , Najberek K., Pocięcha A., Wilk-Woźniak E. 2017. Birds and Alien Species Dispersal: on the Need to Focus Management Efforts on Primary Introduction Pathways. Comment on Reynolds et al. and Green. *Diversity and Distributions* 23: 113-117.


[IF₂₀₁₇: 4,614; IF_{5-year}: 4,777; MNiSW: 45]

H4. **Solarz W.** , Najberek K. 2017. Alien Parasites May Survive Even if Their Original Hosts Do Not. *EcoHealth* 14: S3-S4.

[IF₂₀₁₇: 2,649; IF_{5-year}: 3,000; MNiSW: 30]

H5. Biedrzycka A., **Solarz W.**, Okarma H. 2012. Hybridization between native and introduced species of deer in Eastern Europe. *Journal of Mammalogy* 93: 1331-1341.

[IF₂₀₁₂: 2,308; IF_{5-year}: 1,765; MNiSW: 35]

H6. Najberek K., Nentwig W., Olejniczak P., Król W., Baś G., **Solarz W.**  2017. Factors limiting and promoting invasion of alien *Impatiens balfourii* in Alpine foothills. *Flora* 234: 224–232.

[IF₂₀₁₇: 1,365; IF_{5-year}: 1,633; MNiSW: 25]

- c) The discussion of the scientific objective of the above publications work and the results achieved, together with a discussion of their application

Aim of the above publications

The publications included in this accomplishment address two closely related issues that are key elements of research into biological invasions of alien species. The first one is a parameter determining whether their occurrence in a given area is the result of natural processes (native species) or the result of human activity (alien species). In scientific literature this parameter is referred to as *alienness*. No Polish counterpart has been proposed for this term as yet, and it directly translates into *obcość*. The second parameter analysed in the presented publications is the invasiveness (*inwazyjność*) of species, defined as their negative impact on native biodiversity, economy, as well as human life and health.

The purpose of these publications was to analyse the reasons making the current scientific approach to species' alienness and invasiveness not fully coherent. The effects of insufficient scrutiny in this respect were also analysed, including reliability of conclusions drawn on the

fundamental processes occurring in nature. Based on the results of these analyses, scientific foundations have been developed to increase the consistency of alienness and invasiveness studies.

Problems and their solutions presented in these publications are universal: they apply regardless of the systematic position of the organisms taken into consideration. For this reason, the publications cover a wide spectrum of organisms, differing both in terms of their systematic position and functions that they have in ecosystems. This spectrum includes cyanobacteria, rotifers, species spread by birds, parasites and their carriers, as well as plant and mammal species. Despite such great diversity, in the context of biological invasions, all of the studied organisms combine controversy regarding their alienness, invasiveness, or both of these parameters.

Application of the proposed solutions will contribute to reduction of 'noise' that is currently generated in studies carried out according to inconsistent methodologies of distinguishing alien and invasive species.

Introduction

During the last three decades, research on biological invasions of alien species has been dynamically developing. This is largely due to the need to find effective ways to mitigate the threat posed by these species, both in the context of nature conservation (decline in biodiversity, modification of ecosystem functioning), and economics (losses in the economy, negative impact on ecosystem services) as well as human health, and even people's lives (transmission of disease and parasites, allergies, poisoning, burns). However, introductions of alien species have also become an unintended biological experiment on an immense scale. It created a wide field for conducting scientific research at all levels of organization of life and in every spatial scale. Exploration of the problem of biological invasion has resulted in formulation of a number of new hypotheses, and the results of their testing have a very high cognitive significance for the fundamental areas of biology, including taxonomy, genetics, physiology, biology and ecology of species, biogeography, evolution and ecology of populations and ecosystems (Jeschke 2014).

The progress of knowledge about biological invasions shows at the same time how complex the process is and how difficult it is to solve problems it causes. This results in part from the large diversity of alien species, the ways of their introduction into new areas and habitats they colonise. Moreover, the answer to the question why some alien species do not show invasive properties, while others threaten the local flora and fauna, still remains unanswered. So far, it has not been possible to develop coherent methods to assess the degree of negative impact of alien species, and the mechanisms of this influence are in many cases poorly understood.

The two reasons that fundamentally hinder bridging the gaps in knowledge about biological invasions lie at the heart of the issue. The first one is to define a complete pool of alien species occurring in a given area. The second one is to determine their invasiveness, that is, the level of negative impact on native biodiversity, the local economy, as well as health or life of people.

The pool of alien species is very difficult to determine because of its constant change over time, mainly due to introductions of new species (and to a lesser extent - as a result of dying out of species introduced in the past). In many cases, however, an even greater difficulty is the unambiguous distinction between alien and native species occurring in a given area (Essl et al. 2018). At the same time, the precise identification of the role that humans play in the distribution of organisms (that is, distinguishing between native and alien species) is a key element for understanding the mechanisms governing biogeography, both on a local and global scale. This is particularly important in the context of climate change, which may lead to dynamic changes in the range of native species, often difficult to distinguish from the rapid spread of alien species due to direct introductions by humans. Determining whether a given species is native or alien may also have significant consequences for the current views on the evolution of species themselves, as well as the evolution of interactions between them, such as competition or parasitism. Thus, result of detailed analyses of the alienness of species may consequently indicate the need of fundamental revision of the current perspective about how ecosystems evolve and function (Zenetos et al. 2017, Jarić et al. 2019).

Difficulties with determination of species alienness are further deepened when the problem of their invasiveness is considered. While there is no doubt that only a small fraction of alien species poses a threat in areas where they were introduced (Jeschke 2014), scientific basis for distinguishing a narrow group of those harmful invasive alien species continues to be the subject of scientific debate (e.g. Hawkins et al. 2015, Bacher et al. 2018). A particular challenge in this type of research is, among others, how to determine the invasiveness of such species which on the one hand threaten biodiversity, but on the other hand - have taken over key roles in the functioning of endangered ecosystems (sometimes replacing native species that they had phased out). In addition, the presence of some alien species harmful to biological diversity, brings significant economic benefits or acquires an important social significance, because they have become charismatic", inherent parts of local culture, art or belief (Beever et al. 2019). At the same time, classifying an alien species as invasive may have serious practical consequences, e.g. due to introducing legally binding, expensive and sometimes controversial solutions (e.g. ban of import, eradication) aimed at combating it (Regulation 2014).

Research problems regarding the alienness and invasiveness of species constitute the basic challenge in the analysis of the dynamics of biological invasions in Poland, which I have been conducting since 1999. The approach to biological invasion adopted that time was innovative in our country. Previous studies were conducted from the perspective of individual groups of organisms: alien species were a (usually small) part of all species within the taxa, which the experts specialised in. The research methods applied by individual specialists, including criteria for distinguishing alien and native species, were often unclear and inconsistent. Although the results of such studies were invaluable, there was no synthesis that would allow a comprehensive analysis of the problem of biological invasions in our country. The approach I applied was based on the use of a consistent system for assessing the alienness and invasiveness of species regardless of their taxonomic position. On this basis, a comprehensive critical revision of previous views on whether individual species are native or alien in Poland and an analysis of their negative impact was carried out. I was the co-author of the first

concept of this synthesis, and then I developed it myself, creating in 2003 the database "Alien species in Poland" www.iop.krakow.pl/ias.

This kind of approach to the research topic, in which the basic criterion defining its scope is not the taxonomic position or function performed by the studied organisms in ecosystems but the alienness and invasiveness of species, has become a separate discipline of biological sciences, referred to as invasion biology. Because I have so far analysed about 3,000 species representing the entire taxonomic and functional spectrum, it makes the invasion biology my main field of expertise.

As a result of these analyses, almost 1,800 species have been included in the database "Alien species in Poland", ranging from prokaryotes to mammals. In this type of analysis, apart from knowledge in the field of broadly understood taxonomy, biology and ecology, it is necessary to include elements of Earth sciences and environment (climatology), agricultural sciences (forestry, animal breeding, fishery), veterinary and medicine (parasitology, epidemiology), and even economics and finance (trade in goods), sociological and psychological sciences (motives of actions), law (national and international regulations on e.g. import) or history (e.g. migration of people in the past). If, despite taking into account such a wide spectrum of factors, the current state of knowledge does not allow to resolve these doubts, then the species should be considered as cryptogenic, i.e. one that cannot be classified neither as alien nor as native in a given area.

Interdisciplinary approach used in invasion biology is a very big research challenge. However, this broad perspective provides unique opportunities for perceiving synergies that are not obvious at first glance, for example between organisms that differ in many respects. The problems presented in the publications included in my scientific accomplishment are the result of my experience in this field. They concern issues fundamental to the science of biological invasions, which are exemplified using organisms belonging to very different taxonomic and functional groups.

One of the elements linking all of the species groups I study is the lack of a coherent approach to determining their alienness and invasiveness. This results, among others, in neglecting entire groups of organisms, both in the field of science and the practical approach to biological invasions. An example of such a group are microorganisms. Despite the fact that they play a key role in every ecosystem, in the scientific discourse on biological invasions they are underrepresented (e.g. DAISIE 2009, Roy et al. 2017, Roy et al. 2018). Moreover, the sense of studying the biogeography of microorganisms, and therefore dividing them into native and alien species, is questioned. This results from the belief that the possibility of passive propagation of representatives of this group by natural vectors, such as wind, sea currents or migrating birds, are so immense that they are in fact cosmopolitan species (Finlay 2002, Fenchel and Finlay 2004, de Wit and Bouvier 2006, O'Malley 2007).

The scrutiny with which the issue of alienness of microorganisms is treated seems insufficient, and the potential for revision of the state of knowledge in this area is very large. I drew this conclusion by analysing the biogeography of microorganisms that have been recorded in Poland for the first time in recent years. While there are species for which the distribution

data is indeed very scarce, there is no lack of those for whom the global distribution of records in time and space, combined with other information, could be successfully used to conduct a comprehensive analysis of their native / alien status in areas of the world.

The analysis of the alienness of microorganisms is the subject of two publications included in this accomplishment (Wilk-Woźniak et al. 2016, H1, Pocięcha et al. 2016, H2).

Another conclusion from my research was that the controversy regarding the alienness of species is not limited only to poorly studied microorganisms, in which it is difficult to determine whether a given species is native or alien, mainly due to unclear process that led to its occurrence in a given area. Difficulties in this respect also apply to situations in which the vector responsible for spread of the species is very well defined, even if the size of this species is relatively large, and the knowledge of its biology or distribution seems satisfactory. This is another example of a universal principle of the biological invasion science that operates regardless of the taxonomic position of species. Ambiguity concerns, among other things, the role of climatic changes in the spread of organisms, as well as natural vectors such as migrating birds, wind, rain, sea currents and tsunami waves. Such vectors can transport individuals over very long distances, to areas in which a given species has never been recorded before. Some researchers identify such a way of expansion with the invasion of alien species, while others consider such cases as natural phenomena (CBD 2002, Walther et al. 2009, Webber and Scott 2012, Greene 2015, Reynolds et al. 2015, Incagnone et al. 2015). As a consequence of the lack of coherence in this respect, the comprehensive synthesis and meta-analysis of the causes and effects of invasion can be conducted on the basis of data sets that were collected using completely different and often vague criteria for recognizing species as alien (e.g. Reynolds et al. 2015, Stoyneva 2016). The results of this type of work are therefore neither fully reliable nor can they be compared between.

Unjustified over-representation of alien species in the results of such research, resulting from attribution of this status to species spread by natural vectors, may also have practical consequences. For example, they involve decreasing the assessment of the real natural value of areas, resulting in giving up their protection. Moreover, such results do not provide a strong scientific basis for making efforts to limit the effects of biological invasions. In extreme cases, it may lead to wrong decisions to combat species, which undoubtedly naturally occur in an area, but were mistakenly considered undesirable alien species (Simberloff 2012).

The analysis of the significance of natural vectors of species spread for their alienness has been presented in the articles on the spread of organisms by birds (Solarz et al. 2017, H3) and the spread of parasites by their hosts (Solarz i Najberek 2017, H4). These articles also address the invasiveness of alien species.


The results of my research indicated that the link between the abilities of alien species to expand and their invasiveness is so strongly established in the scientific community (Blackburn et al. 2011, Lenda et al. 2015) that the terms "expansive" and "invasive" are often used

interchangeably. Consequently, the pool of invasive (i.e. having a negative impact) species is mostly represented by those species whose expansion has led to occurrence over large areas. As in the case of ambiguous criteria applied to species spread by birds, the issue concerns organisms in the whole taxonomic spectrum.

At the same time, threats resulting from the presence of species that occur over short time period and in a restricted area are usually ignored, thus such species are not considered invasive. However, the transmission of parasites by alien species poses the risk of triggering dangerous epidemics even if only one infected host is present in the environment, and even for a short period of time (Solarz and Najberek 2017; H4). In addition, even single individuals of alien species may hybridise with related native species. Another universal issue for biological invasion, irrespective of the organism considered, is the effect of changes in the environment, such as climate warming, on the invasiveness of species.

Analysis of the invasiveness of alien species, which are rare in the natural environment, is continued in the publications on hybridisation of the Asian sika deer *Cervus nippon* with the red deer *C. elaphus* (Biedrzycka et al. 2012, H5) and factors influencing the expansion of the non-invasive Asian Balfour's balsam *Impatiens balfourii* (Najberek et al. 2017, H6).

Results

H1. Wilk-Woźniak E., Solarz W. , Najberek K., Pocięcha A. 2016. Alien cyanobacteria: an unsolved part of the “expansion and evolution” jigsaw puzzle? *Hydrobiologia* 764, 65-79.


This paper presents results of analysis of the alienness and routes of expansion of three species of cyanobacteria. Despite the key role in the functioning of ecosystems and despite causing dangerous blooms, this group of organisms is surprisingly poorly represented in biological invasions research. The article analyses three species of cyanobacteria considered by most researchers as alien in the temperate zone in Europe: *Cylindrospermopsis raciborskii*, *Raphidiopsis mediterranea* and *Cuspidothrix issatschenkoi*. In the absence of direct evidence of human role in the spread of these species, the spatial and temporal pattern of their global distribution, including available paleolimnological data, as well as information on morphology, genetics, taxonomy and ecology were analysed. Characteristics of the environments they colonised were also taken into account. This analysis provided a broader context for consideration of the expansion and evolution of cyanobacteria.

Each of the three studied species has been found almost on all continents and in different climatic zones. The article analyses the expansion routes of these species. The following expansion routes have been identified for *C. raciborskii*: (1) from Central Africa to North Africa, (2) from North Africa to Europe, (3) from Java to eastern Australia, (4) from Java through southern Asia to Europe, (5) from Australia to southern Africa and further to the eastern part of both Americas. The identified expansion routes for *R. mediterranea* are as follows: (1) from southern Europe to the north and west of the continent, (2) from southern Europe to northern Africa, (3) from Europe to the east coast of North America. The status of records in South Asia and Australia is not clear. It is possible, however, that from these areas the species has spread

to the eastern coast of South America. The proposed routes of expansion of *C. issatschenkoi* include the following directions: (1) from western Asia to Europe, (2) from Europe to the east coast of North America, (3) from New Zealand and Australia to east Asia, (4) from New Zealand and Australia to southern Africa and further to the east coast of South America.

The results of these analyses indicate that even in the case of poorly studied microorganisms, their biogeography should be considered not only in the static context of their current distribution of records, but taking into account the spatio-temporal aspect. In addition to the innovative proposal to reconstruct the pathways of expansion, our detailed analysis made it possible to draw conclusions about the close connection between the processes of expansion and evolution, especially in the context of human influence on the rate of both processes. Regardless of the reason for the occurrence of the studied organisms in new areas, their local success can undoubtedly be attributed to large phenotypic and genetic diversity. It allows quick adaptation and survival in new conditions, which in the face of geographical isolation of new populations - promotes speciation. One of the consequences of introducing species by humans into areas that they would not be able to conquer themselves, can therefore be an increase in the rate of evolution. This is especially important in the case of microorganisms, such as cyanobacteria, where the process of speciation can occur relatively quickly.

However, attention should be paid to the fact that although drawing conclusions about the ways of expansion of the studied species is justified both by the data on their distribution and about genetics, it is not possible to clearly determine the role that the man played in every case. Therefore, at the present level of knowledge, the studied cyanobacteria cannot be considered as species certainly alien in Europe. However, even in cases where the available information is very restricted or difficult to verify, postulating unclear status of species should not be a result of a merely superficial assessment of data availability; even lack of clarity in this respect should always be documented by the results of a systematic analysis.

H2. Pociecha A., Solarz W. , Najberek K, Wilk-Woźniak E. 2016. Native, alien, cosmopolitan, or cryptogenic? A framework for clarifying the origin status of rotifers. Aquatic Biology 24: 141–149.

The experience gained during the analyses of biogeography of cyanobacteria (Wilk-Woźniak et al. 2016; H1) confirmed that a transparent and rigorous methodological approach to the problem of species alienness should be applied even if the amount of information we have is very restricted. The problem of the status of microorganisms was continued in a publication on freshwater rotifers occurring in Europe. This work presents a comprehensive system for assessing the alienness of species. By using a formalized procedure, this system maximizes the effectiveness of utilising available information on the distribution and biology of species, as well as about their expansion scenarios on a local scale. Both – the existing data and their total absence, are subject to rigorous assessment and have an equal impact on final decisions regarding status. The basis for this system was a scheme developed for determining the alienness of marine crustaceans, consisting of 10 attributes characterizing alien species (Chapman and Carlton 1991). To verify the status of freshwater rotifers, the usefulness of these attributes was evaluated, resulting in modification of 8 of them and adding a new one.

In addition, a parameter reflecting the level of certainty was introduced to the assessment. The analysed attributes included: (1) emergence in areas where the species has not been found so far; (2) an increase in the number of local records in areas where the species appeared; (3) connection with anthropogenic means of spread; (4) connection with other alien species; (5) connection with human-transformed environments; (6) small range of occurrence in the analysed area compared to related native species; (7) isolated populations occurring on different continents; (8) local absence of related species; (9) deviation from natural state of habitat(s) in which the first local records of the species were made. Detailed criteria have been specified for each attribute, indicating if the species is native or alien.

The system calibrated in this way was tested on a sample of 16 species of rotifers, which in previous publications were referred to as alien or new species in Europe, as well as cosmopolitan or tropicopolitan (occurring in the tropic zone). Each of these species has undergone a detailed analysis in which appropriate values were assigned for each of the 9 attributes of alienness. This value indicated the native or alien origin of the species. In case of doubts that could not be clarified and in case of complete lack of data, the assigned value indicated the cryptogenic status of the species. Based on the total result obtained for all attributes considered, the status of the species was determined along with the measure of the certainty of this assessment.

Of the analysed species, 11 were classified as alien in Europe; these were species for which at least half of the analysed attributes scored values indicating human participation in their introduction into Europe. The status of 4 of these species has been determined with high certainty, another 4 - with a medium, and 3 - with a low certainty. Interestingly, in earlier publications only 3 of these species were considered alien. The results obtained for the remaining 5 out of 16 studied species did not allow to determine whether they are alien or native in Europe, therefore they were classified as cryptogenic species, with high certainty of this assessment. One of these rotifers was previously considered an alien species in Europe. Among the assessed attributes, the most effective predictors of alien status were "unexpected" detection of the species in well-studied areas where it did not occur before, as well as a small area of occurrence in the analysed area compared to native species.

It should be noted that collating and detailed analysis of previously dispersed data resulted in change of the current status of 3/4 of the studied species. This result indicates the need of a critical revision of current, largely arbitrary views on the origin of microorganisms, which should be carried out using a transparent and repeatable methodology. An advantage of the proposed approach is its simplicity: it does not require high resources to conduct new research in order to supplement missing information. Instead, previously collected, but dispersed data, should be integrated and the degree of their completeness should be assessed. If necessary, the results of the assessment carried out in this way can then be verified using more complex and costly methods, such as genetic analyses. Another advantage of the proposed methodology is its versatility, because it can be applied not only to aquatic microorganisms, but also to other species groups as well as other environments. This may require modification of the proposed criteria, including excluding some of them, or adding new ones.

First of all, however, formalizing the process of assessing the alienness of microorganisms, in contrast to arbitrary assessments, creates a platform for scientific discussion both on the individual elements of the analysis and on its final output. If results of the new studies appear, the current assessment procedure can be easily supplemented. Thanks to this versatility, the earlier conclusion can be confirmed or questioned, including a complete revision of the current views on the origin of the species in the assessed area.

H3. Solarz W. , Najberek K., Pocięcha A., Wilk-Woźniak E. 2017. Birds and Alien Species Dispersal: on the Need to Focus Management Efforts on Primary Introduction Pathways. Comment on Reynolds et al. and Green. Diversity and Distributions 23: 113-117.

In this article the problem of the alienness of microorganisms (Wilk-Woźniak et al. 2016; H1, Pocięcha et al. 2016; H2) is continued. At the same time, it is my input into the debate in the Diversity and Distributions journal, concerning the role of natural vectors in the transfer of alien species. This discussion was initiated by an article on the role of waterbirds in the dispersal of alien species (Reynolds et al. 2015), which was then critically supplemented by Green (2015). Together with colleagues who I previously worked with on the alienness of microorganisms, I discussed with the theses presented in both of these articles. This, in turn, triggered a joint response of the authors of both earlier works (in which they had discussed among themselves; Reynolds et al. 2017), who largely agreed with my arguments.

Both Reynolds et al. (2015) and Green (2015) correctly point out that the role of birds is often neglected in the analyses of alien species spread. The authors consider it to be a serious failure, limiting the effectiveness of efforts to mitigate the problem of biological invasions. However, my experience gathered during the analyses of species status indicates that the basic reason for the lack of birds in assessments of invasion routes is that their natural migrations in fact do not play a significant role as the primary cause of introduction of alien species into new areas.

The incorrect, in my opinion, conclusion that this role may be important, results from misinterpretation of two processes. First of all, new species that are spread over long distances by birds, are mistakenly treated as alien species. However, due to the fact that migrations of native bird species are a completely natural phenomenon, all species that these birds disperse should be consistently treated as native. Even if such species come from very distant, "exotic" areas, humans did not play any role in their spread, therefore there are no reasons to consider them to be alien species. Secondly, although on a local scale birds can indeed increase the rate of biological invasions, this applies only to the transfer of such alien species, that have already been introduced here due to various types of human activity. In this case, the role of birds in biological invasions, however important it may be, is therefore only secondary to the role of humans.

Nevertheless, in specific situations, new species brought by migrating birds should indeed be considered alien. The criteria of such decisions, presented in this publication, constitute a completely novel aspect of the discussion on determining the alienness of species. This criterion is met when a new species has been introduced into a given area by a bird species

that itself is alien here; for example, it escaped from captivity or was deliberately released in a distant area. If a bird of such an origin becomes a vector transferring new species into a given area, then also appearance of species that is bringing, should be considered as an indirect result of human activity. This criterion is also met when such a newly introduced organism is already an alien species in the "starting point" from which it was taken by the bird taking off. The analysis of available information showed that there are no known examples that could illustrate the above scenarios. This may be caused by lack of unambiguous criteria for determining the alienness of species dispersed by birds, resulting of ignoring this issues in earlier studies.

The paper also presents the results of the analysis of ways to manage the risk of local increase of the rate of invasion due to birds spreading alien species that have been introduced to the area by humans in the past. Both Reynolds et al. (2015) and Green (2015) indicate the need for further basic research on this type of dispersion. Arguing with this statement, I showed that in view of the almost unlimited time and spatial scale in which this vector operates (like other natural vectors, such as wind or sea currents), improving the state of knowledge in this area will not translate into increased effectiveness of actions aiming at reducing the risk. Regardless of the state of this knowledge, the three-stage hierarchical approach, recommended by the Convention on Biological Diversity (CBD 2002), remains the basic principle to follow. This approach has been analysed in detail in the paper, in the context of dispersal by birds. The most effective method is to prevent new introductions of alien species, which could then be locally spread by birds. The second line of defence is the early detection of cases of new introductions and undertaking quick actions to prevent establishment and spread of alien species. If this is not possible, long-term control of such species should be applied, especially in areas of high natural value. On the other hand, the main goal of research should be to identify areas that can play a key role as a source of local secondary invasions due to dispersal by birds.

Practical application of the results of these analyses will increase effectiveness of actions to control alien species.

H4. Solarz. W. , Najberek K. 2017. Alien Parasites May Survive Even if Their Original Hosts Do Not. Ecohealth 14: S3-S4.

This is another paper analysing the problem the species alinness and the role of natural vectors in species spread. It is a voice in the discussion in the journal EcoHealth (Blackburn and Ewen 2017) that in an innovative way presents aspects that were previously neglected in the context of biological invasions. According to prevailing opinions, alien species of parasites have lower chance of success after being introduced to new areas than hosts that carried them here. This is supposed to be a consequence of the fact that if the hosts are not able to establish in new areas, the fate of their parasites is invariably the same (Blackburn and Ewen 2017). In this publication I criticised this view, arguing that the survival of an alien parasite and the infection of the native host is possible even if its original host will die soon after introduction. The analysis presents the reasons why such a scenario should not be ignored in risk

assessments. I also defined reasons that, by definition, make it difficult to collect evidence supporting the theses I have presented. However, as shown in the examples presented – such evidence is possible to collect. I also drew attention to the consequences of the lack of a rigorous approach in determining the status of newly detected species of parasites, both for the theoretical aspects of biogeography and taxonomy, and for practical solutions to the problem of biological invasions. At the same time, the article deals with controversies regarding the classification of such ephemeral species as invasive.

I demonstrated that infection of native species by an alien parasite, whose original host died after the introduction, is possible, among others, because the complex developmental cycle of some parasites includes free-living larvae, as well as eggs and resting stages (for example cysts). Consequently, after death of the original host, they can survive in the environment long enough to find and infect a new, naïve host. In addition, some parasites may be less susceptible to factors that have caused their original hosts to quickly die shortly after being introduced into new areas. For example, the internal parasites of exotic birds and mammals, even after being introduced into areas with a climate lethal for their hosts, may find suitable conditions for further development within the previously unknown warm-blooded, native host species. Alien parasites are more likely to establish than their original hosts also because their success is less dependent on the number of introduction events and the number of introduced individuals. This is due to the fact that asexual reproduction and hermaphroditism are more common among parasites than among their hosts. Thus, while the necessary condition for the reproduction of the host, and consequently, its possible establishment and expansion, is introduction into the same area and at the same time at least one male and one female, the invasion of parasites can occur even after introduction of just one infected host, regardless of its sex, age or condition.

The publication analyses several examples of the scenarios described above. The small number of known cases results, first of all, from the fact that the chance to document them is inversely proportional to the time that the alien host species is able to survive after the introduction to the new area. In many cases, this time is so short that the host dies even before its presence is detected. Under this scenario, there are no indications whatsoever that this host species was present in the environment, let alone that it was a vector of a new parasite. This is particularly true for species accidentally introduced (no documentation of introduction), as well as those that belong to poorly studied groups (difficulties in detecting and identifying species) or introduced in poorly studied areas. Also very old introductions are usually poorly documented, even if they were successful. Linking newly detected parasites with the presence of the host, whose occurrence is unknown, can obviously be very difficult.

However, poor knowledge about novel interactions between alien parasites and native hosts results also from ignorance of scientists dealing with biological invasions. Records of such species are often publicised by the media, especially in case of attractive or dangerous exotic species. However, because such species have no chance to establish, they are treated as non-invasive and regularly fall off-the radar of science.

The presented results have significant practical implications, first and foremost, for risk assessments of alien species, resulting, for example, in imposing legal regulations.

Parasites are another, after cyanobacteria (Wilk-Woźniak et al. 2016; H1) and rotifers (Pociecha et al. 2016; H2), group in which I called for a rigorous approach to determine whether they are native, alien, or cryptogenic. It is necessary in this case, because if an unknown parasite is detected in a native host and the original, alien host died so soon that its presence in the environment was not even noticed, there are often no premises whatsoever that such a new parasite may be an alien species. It can therefore be mistakenly classified as a local, native parasite. Moreover, the new taxon discovered under such a scenario may be mistakenly described as native in its *locus typicus*. Consequently, such wrong decisions regarding the alienness of species result in 'falsification' of the true structure, evolution and functioning of ecosystems. Such errors may also affect incorrect decisions aiming at reducing the negative impact of species that have been mistakenly classified as alien, including their eradication or management of routes of their introduction.

H5. Biedrzycka A., Solarz W., Okarma H. 2012. Hybridization between native and introduced species of deer in Eastern Europe. Journal of Mammalogy 93: 1331-1341.

As demonstrated in the publication on parasites (Solarz and Najberek 2017; H4), the negative effects of the presence of alien host species can be detected even after their extinction. Therefore, in some cases the invasiveness of alien species, defined as their negative impact, is not directly dependent on their numbers in the natural environment. Another article that confirms this thesis, analyses invasiveness of the Asian sika deer *Cervus nippon*. Although it has been a permanent element in Poland's fauna for more than a hundred years (Solarz 2011), only two small populations in our country occur – near Pszczyna and near the Vistula Lagoon. Due to the small number and limited range of occurrence, until recently the sika deer was considered a non-invasive alien species in Poland (Solarz 2011). In contrast, in countries with large sika populations, such as the United Kingdom, it was found that it interbreeds with the red deer *C. elaphus* (Goodman et al. 1999, McDevitt et al. 2009, Senn and Pemberton 2009).

Similarly to other types of alien species impact, it is considered that hybridization with native species is dangerous if the number of the alien species is high (Schierenbeck 2011). However, detailed genetic analyses of red deer and sika deer, carried out in the project that I took part in, clearly demonstrated the impact from hybridisation may be high when the number of alien species is very small. Moreover, the scale of hybridisation (15.5% of hybrids, including individuals from Lithuania and the Kaliningrad region) was higher than in the British Isles (on average below 10%, Goodman et al. 1999, McDevitt et al. 2009, Senn and Pemberton 2009). In most cases, sika deer bulls crossed with the red deer hind. The presence of hybrids was found not only in the area of the permanent occurrence of small sika deer populations, but even in a place where only single individuals were sporadically observed. It can be assumed that hybridization has been occurring throughout the entire century after the introduction of sika deer into Poland. However, the scale of this phenomenon has only been demonstrated by genetic analyses. Earlier field observations never confirmed that hybridisation between the two deer species occurred at all, because hybrids were impossible to identify on the basis of phenotypic traits.

The paper presents recommendations for reducing the threat from sika deer. It is necessary to limit intentional introductions and escapes of this species from captivity, as well as to control the numbers of the free-ranging population.

H6. Najberek K., Nentwig W., Olejniczak P., Król W., Baś G., Solarz W. ✉ 2017. Factors limiting and promoting invasion of alien *Impatiens balfourii* in Alpine foothills. *Flora* 234: 224–232

Another paper on threat of alien species with small population numbers analyses expansion of the Balfour's impatiens *Impatiens balfourii*. Originating from Asia, at the beginning of the 20th century it was imported to Europe for ornamental purposes (Adamowski 2009). In contrast to the closely related Himalayan balsam *I. glandulifera*, which is one of the most invasive alien species in Europe (Regulation 2011, 2014), the Balfour's impatiens is considered an invasive species only locally and its range in Europe is limited (Banfi and Galasso 2010, Fried et al. 2014). In Poland, this species has not been recorded so far (Tokarska et al. 2012). However, restrictions imposed on the Himalayan balsam may cause that the Balfour's impatiens replaces it in trade and cultivation, and consequently – is introduced into the wild. In an experiment carried out in the Institute's field station in Zakopane, along with my colleagues, I demonstrated that this species can be successfully grown in Poland, even in mountainous areas, where the climate is severe.

Understanding the mechanisms of acquiring invasive characteristics by species that currently do not pose a threat is important both for the theoretical aspects of biological invasions and for assessing the future risk from non-invasive species and finding ways to reduce it. The research, whose main goal was to analyse the reasons for the slow expansion of the Balfour's impatiens, was carried out in Insubria, on the border between Switzerland and Italy. Habitat preferences of the species and the condition of individuals growing in various habitats were examined, as well as the level of pressure from diseases and pests.

Over 3/4 of the 70 detected locations were situated in Italy; nearly all of them were along roads. This pattern was significantly different on the Swiss side, where only 4 roadside locations were detected. There were no differences in the physiography of the studied area on both sides of the border. The area of the roadside locations of the species was positively correlated with the presence of buildings, but it did not depend on the distance from the road or elevation above sea level. However, the zero-one analysis showed that the elevation, as well as insolation, has a limiting effect on the Balfour's impatiens (the maximum elevation of the detected location was only 477 m a.s.l.).

Individuals growing along roads were largest, while the heaviest seeds were produced by plants growing in ruderal habitats. Individuals growing in forests produced the lightest seeds and had the lowest number of flowers. Of the more than 8,500 leaves inspected, 39% were damaged, mainly by diseases: rust and stains accounted for 57% of damage. Individuals growing along roads were least affected by diseases. However, only 16% of the 226 invertebrates recorded on plants were pests (mainly snails). The level of pest pressure was similar in all habitats.

Since the overall level of pressure from diseases, and especially from pests, is very low, it seems that this is not a key factor limiting the invasiveness of the Balfour's impatiens. On the other hand, the low tolerance for slight changes in altitude indicates that the temperature may be such a factor. Thus, the synergistic effect of the evolution of traits that facilitate invasion (increased tolerance to low temperatures) and changes in climatic conditions may in future lead to an increase in the rate of invasion and threat from this rare and non-invasive species, also in areas where it currently does not occur at all.

An important conclusions in this context can be drawn from differences in the distribution of impatiens in neighbouring areas on the Italian and Swiss sides, identical in terms of physiography. On the Swiss side, the density of buildings along the roads was higher, which could increase the scale of escapes of individuals from home gardens thanks to the ballistic seed dispersal. Nevertheless, it was virtually absent along the roads. Undoubtedly, this is the result of differences in the roadsides maintenance regime. On the Swiss side they are frequently and thoroughly mowed, whereas on the Italian side mowing is carried out less frequently and only along sections running in built-up areas. As a result, on the Swiss side, roadsides constitute an ecological trap for the Balfour's impatiens. Despite the constant propagule pressure from home gardens and although roads, as a linear structure, favour the spread of the species from the Italian side, and individuals along roads are large and released from diseases and pests, fitness of most individuals that managed to germinate here is equal to zero: they fail to develop into the flowering phase and produce seeds. It can therefore be concluded that mowing is currently a very effective way to further reduce the invasiveness of the Balfour's impatiens. However, the results of this research indicate that climate change may cause the species to spread to the level that will make its control impossible.

Summary and application of the results

The most important result of my scientific accomplishment is introduction of innovative aspects to the ongoing scientific discourse on the alienness and invasiveness of species. In my opinion, too little attention in this context has been given mainly to microorganisms and species spread by natural vectors, such as migrating birds or carriers of parasites. Lack of sufficient rigour in this respect may have significant consequences for the fundamental fields of biology, introducing some kind of 'noise' affecting credibility of reasoning about the processes of species evolution, their biogeography and interactions, and consequently – the evolution and functioning of entire ecosystems. The practical effect of shortcomings in the scientific field is decreasing the effectiveness of solutions aimed at mitigating the problem of biological invasions.

In my articles, not only did I draw attention to this problem, but also proposed scientifically sound solutions, including the framework analysing the status of microorganisms – a group that plays a fundamental role in ecosystems, and yet in the research on biological invasions is poorly represented. Assessments of the status of microorganisms were usually underrepresented in previous studies, or based on arbitrary evaluation. In contrast, my approach follows appropriate rigour of scientific research, providing transparent results and

allowing for substantive discussion. Moreover, such a platform can be used to effectively bridge the gaps in the biogeography of species, as it uses the information already collected, which only requires structuring and analysis. Gaps in knowledge in this area are particularly pronounced among microorganisms, but the approach that I proposed is very flexible and can be adapted to different groups of organisms and different environments. This approach has been practically applied for analyses of species status for the purposes of the database 'Alien Species in Poland'.

In addition, I have critically revised the current approach to organisms spread to new areas by natural vectors, such as migrating birds. In the face of misunderstandings involving identification of species utilising these vectors as alien, I proposed criteria that unequivocally distinguish between native and alien species. The use of my results will ensure the coherence of research into natural vectors of species distribution. I also pointed to the necessity to increase the usefulness of this kind research, by focusing on syntheses defining the priority areas acting as sources of local invasions, instead of case-by-case analyses of relationships between particular species and vectors spreading them. The practical application of the results of my research will therefore contribute to increasing the effectiveness of activities aimed at controlling alien species.

I have also critically analysed the dominant view of the relationship between the invasiveness of alien species and their numbers and level of spread. I have shown that alien species can be dangerous even when their populations are small, and even if they are not established at all. A completely novel aspect of this research was the demonstration that the negative impact of alien species that carry parasites can manifest even after they have completely died out in the area where they had been introduced, because parasites they brought are capable of infecting new native hosts. I analysed reasons making detection of such a mechanism very difficult, and indicated why it is almost completely ignored both in current research on biological invasions and in practical efforts to limit their effects.

The results of my research have been taken into account, among others, in the development of species risk assessments, for the EU Regulation on invasive alien species. The results of study into hybridization between sika and red deer were directly applied even before they were published. After submitting a report to the General Directorate for Environmental Protection (GDOŚ), sika deer was included into the list of 52 invasive alien species, for which restrictions on possession and trade were introduced in Poland (Rozporządzenie 2011). As a consequence, GDOŚ decided to develop a management strategy for this species in Poland, which I co-authored (Solarz and Okarma 2014), and the Polish hunting authorities of the Polish Hunting Association recommended eradication of sika deer from Poland (PZŁ 2015).

I have also shown that in the future, due to climate change, alien species that are currently rare and non-invasive, can develop invasive traits. The results of these studies were used in development of the national strategy on alien species in Poland.

5. Discussion of other scientific and research (artistic) accomplishment

A detailed list of accomplishments in the field of science, education and popularisation is included in Appendix 6. The numbers of publications, projects and assessments, provided below, correspond to numbers in Appendix 6. These publications were not included in the list of references in the present document.

Accomplishments before completing PhD degree

As I have been interested in birds since my childhood, I studied biology. I was the chairman of the Ornithological Section of the Society of Naturalist Students of the Jagiellonian University. My master thesis analysed factors shaping avifauna in quarries, and its results were presented in my first scientific publication (Solarz 1997 P25). As a PhD student at the Institute of Nature Conservation PAS, I obtained funding from the Scientific Research Committee (KBN) for a project in which, as a principal investigator, I studied ecology of the sedge warbler *Acrocephalus schoenobaenus* in the source-sink population dynamics (Appendix 6, project G1). Based on the results of this project, I wrote my PhD thesis and several papers were published, with me as an author or co-author (Król et al. 2002 P01, Zajac et al. 2003 P28, Solarz 1998 P26, Solarz and Zajac 1998 P27). The Polish counterparts that I proposed for the English "source-sink" ("źródło-ujście"; Solarz 1998 P26) have been widely accepted in Polish vocabulary in ecology.

In 1999, I started to study the problem of biological invasions, joining the team coordinating a comprehensive analysis of the threat posed by alien species in Poland for the Ministry of the Environment. It was a pioneering approach to this topic in our country.

Accomplishments after completing PhD degree

After obtaining the PhD degree, I continued studying the sedge warbler population in which I participate until today. Throughout this period, I was an investigator in 4 projects financed by KBN and the National Science Centre (NCN), which dealt with various aspects of ecology of this species (Appendix 6, project G3, G7, G12) and its habitat (G2 project), and co-authored a series publications on this subject (Zajac et al. 2006 P03, 2008a P05, 2008b P06, 2011 P12, 2015 P13, Biedrzycka et al. 2017 P19, Biedrzycka et al. 2018 P23, Bielański et al. 2005 P32, 2017 P18). The results of these studies were also presented at numerous national and international conferences (Appendix 6, points IIK and IIIB).

However, the main topic of my research after obtaining the PhD degree are biological invasions of alien species. Since 2003, I have been responsible for conducting comprehensive analyses of the dynamics of biological invasions in Poland. Throughout that period, I carried out an analysis of the occurrence of nearly 3,000 species, almost 1,800 of which were assessed as alien species in Poland and included in the database. I am the author of the concept of this database and its editor and administrator. At the same time, I established scientific cooperation with about 100 experts from around 30 scientific institutions in Poland. This scientific network of collaborators deals with species in the database. The results of these surveys are regularly communicated to the Ministry of the Environment, for example as an

early warning against possible invasions of new invasive alien species in Poland, or about their negative impact.

In 2003, I started cooperation with the US Department of State and obtained a project grant (Appendix 6, project G18) that allowed making the database available on the Internet, as 'Alien Species in Poland' (www.iop.krakow.pl/ias). It is the most comprehensive source of information on alien species in our country. In 2009, a new structure was developed and since then the database has had over 920,000 views (the total estimated number views in 2003-2019 is 1,500,000). In cooperation with the Ministry of the Environment, I am also responsible for integrating information from Poland for analyses at the level of the region (NOBANIS www.nobanis.org) and Europe (DAISIE www.europe-aliens.org), including the European Commission (EASIN <https://easin.jrc.ec.europa.eu/>), as well as on a global scale (GRIIS www.griis.org).

The results of these studies contributed to several publications which I authored and co-authored. Particularly important in this context is my participation in two projects of the 6th Framework Program of the EU (Appendix 6, project G5, G6), as well as in the COST project (project G16). In these projects I took part in complex analyses concerning a broad spectrum of organisms and environments. They addressed, among others, routes of invasion (Hulme et al. 2008 P07, Kark et al. 2009 P39, Pyšek et al. 2010a P10), climate impact on alien species (Walther et al. 2009 P09), the impact of environmental and anthropogenic factors on invasions (Pyšek et al. 2010b P11, Solarz et al. 2010 P41), as well as their effects (Vilà M. et al. 2006 P35), methods of risk analysis (Roy et al. 2017a P16) and threats from alien parasites (Roy et al. 2017b P17), and species that are not yet present in Europe, or their populations are still very small (Roy et al. 2018 P22).

In 2004, I was in the coordination team of the KBN project in which threats from invasive alien animal species in Poland were comprehensively assessed (Appendix 6, project G4). The results of this project have been presented in a two-volume monograph. I was the co-editor of one volume (Głowaciński et al. 2011 P42) and the author and co-author of 11 chapters (Głowaciński and Solarz 2011 P49, Głowaciński et al. 2011 a,b P50-51, Najberek and Solarz 2011 a,b P52-53, Solarz 2011 a,b,c,d,e P43-47, Solarz and Okarma 2011 P48). In 2011, the results of these studies were published on the Internet (www.iop.krakow.pl/gatunkiobce). The estimated number of hits for this portal is 700 000.

I participated in 5 other projects related to biological invasions, financed by the NCN. As the principal investigator, I carried out a project analysing factors determining the invasion of goldenrods in the Polish Carpathians (Appendix 6, project G15) and the impact of climate, habitat and human pressure on the distribution of plants and birds in Małopolska (project G10). As an investigator, I carried out a project verifying the enemy release hypothesis on selected species of native and alien plants in the Polish flora (G11 project), a project analysing social attitudes towards dealing with alien species in Poland (G9 project), and also a project on the mammal fauna in Poland (project G13). As a result of these projects, a number of papers were published (Najberek and Solarz 2016 P61, Najberek et al. 2016 P15, 2017 P20, 2018 P24, Olszańska et al. 2016 P14) and the Atlas of Mammals of Poland was made available on the Internet (www.iop.krakow.pl/ssaki).

I am also the author and co-author of a few dozen of other works on biological invasions, published as articles in peer-reviewed journals and chapters in monographs and academic textbooks, as well as the author of 9 other publications (Appendix 6, P25-61.)

The results of my research on alien species have been presented at more than 50 international and national symposia, conferences and workshops. I was also an invited speaker e.g. at the University of Tsukuba, University of Bern, Center for Ecology & Hydrology in Wallingford and at Polish universities (e.g. UJ, UŚ, UAM, UWr; Appendix 6, points IIIK and IIIN).

I was the organiser of 2 international and 2 national conferences on biological invasions (Appendix 6, point IIIC).

I am the author of 11 reviews of publications and 1 international project on biological invasions (Appendix 6, points IIIO, P).

I was the co-supervisor of one doctoral dissertation (Appendix 6, item IIIK), and supervisor of 3 master theses and 9 BA dissertations of the UJ students, dealing with biological invasions. In addition, I supervised 11 students in apprenticeship at the INC PAS (Appendix 6, IIJ).

In 2009-2014 and 2014-2015, I was a member of the National Council for Nature Conservation, responsible, among others, for issues related to biological invasions. As part of this work, I prepared a number of opinions and assessments on this subject.

I am a member of almost 30 international and national consortia, research networks, organisations and scientific societies (Appendix 6, IIIE, F, H). One of them is the Bern Convention expert group on invasive alien species. I have been its member since 2003. In 2011-2015, I was its vice-chairman and since 2015 I have been its chairman. This group prepared, among others "European strategy on invasive alien species" (Genovesi and Shine 2004), as well as a series of recommendations for governments and 11 codes of good practice on invasive alien species. In 2004, as the first Polish expert, I was invited to become a member of the Invasive Species Specialist Group of IUCN (www.issg.org) and until today I remain the only Polish representative in this group. One of my tasks as part of this team's work is exchange of information on alien species on a global scale (www.griis.org). Since 2004, I have also been a member of NEOBIOTA - European Group on Biological Invasions, and since 2008 I have been a member of the Council of this group. Since 2014, I have been part of an international team of scientists working for the European Commission on the risk of introducing, establishment and spreading of new alien species in Europe. In addition to the strategic documents prepared for the Commission, scientific publications are also produced as a result of the work of this team (Roy et al. 2017 a,b P16-17, Roy et al. 2018 P22). In 2007-2010, I was a member of the Scientific Council of the Institute of Nature Conservation of the Polish Academy of Sciences.

Biological invasions have become my passion not only because they provide a unique opportunity to conduct interesting, interdisciplinary scientific research. Equally satisfying is that in my work there is a perfect feedback between science and practice. My scientific accomplishments have regularly constituted the scientific basis for implementation of practical solutions both in Poland and internationally. In turn, participation in this type of

practical activities provided me with the opportunity to conduct prolific scientific research. My experience in this field dates back to 1999, since I have been cooperating with the ministries of the environment, agriculture and foreign affairs. The results of my research on alien species have been directly applied into a series of analyses and studies prepared by me for these ministries (Appendix 6, IIE and IIIM). I participated in the work of the parliamentary subcommission on nature conservation act, including my proposals to include the terms "alien species" and "invasive alien species" into this regulation (Ustawa 2004). On the basis of my two assessments (Solarz et al. 2005 E2, Solarz 2008 E3) a decree of the Minister of the Environment was prepared, introducing restrictions for the most invasive alien species in Poland (Regulation 2011). I was also the leader of a team of experts who developed the procedures for implementing this regulation (Solarz et al. 2012 E7). In addition, I was a co-author of management programmes for sika deer (Solarz and Okarma 2014 E9) and alien turtle species (Kepel et al. 2015 E13). Moreover, I prepared analyses on the national implementation of the EU regulation on invasive alien species at the administrative (Solarz 2014a E10) and legal (Solarz 2015b E11) level. As of 2016, I am a member of the IUCN panel of experts providing the European Commission with support for the implementation of this regulation at the EU level. On the basis of risk analyses that I carried out for the European Commission (Mazurska and Solarz 2016 E15, Solarz 2016 E16), the Egyptian goose *Alopochen aegyptiacus* was included in the EU regulation in 2017, and the American bison *Bison bison* was considered one of the most dangerous alien mammals in Europe (Roy et al. 2018 P22). I also participated in the development of a code of good practice for the use of alien plant species in horticulture (GDOŚ 2014). In addition, I prepared several other assessment and expert opinions for the US Embassy in Warsaw (Solarz 2004 E30), European and Mediterranean EPPO Plant Protection Organization (Solarz 2007a, b E33-34), and the Secretariat of the Convention on Biodiversity CBD (Solarz 2007c E38).

A particularly ambitious task combining scientific research with its practical implementation was the development of a national strategy for alien species until 2030 for GDOŚ (Appendix 6, G20 project). As part of this project, I have established cooperation with over 100 experts from around 30 research institutions. As a co-leader of the entire research team, I was responsible for developing a methodology, including analyses of invasiveness, species spread and dynamics, their impact on the natural environment, economy, human health, ecosystem services, the impact of predicted climate change on invasiveness, as well as methodologies for priority species, and the priority pathways for their introduction to Poland. In addition, I am the co-author of the whole strategy (Solarz et al. 2018a E17), as well as of a comprehensive action plan (Solarz et al. 2018b E18), risk assessments for 30 species (Solarz 2018a, b E19-20) and management plans for the most dangerous pathways of their invasion (Solarz et al. 2018c,d E21-22). These strategic documents will be successively implemented by 2030, not only by the Ministry of Environment, but also by other ministries dealing with alien species (including the Ministry of Agriculture, Economy, Justice, and Home Affairs). These studies have been used, among others to prepare the law on alien species, due to be adopted in 2019.

As an expert of the Ministry of the Environment and GDOŚ, since 2001 I have been a member of scientific teams which, under several international Conventions, including on Biological Diversity (CBD), Bonn (CMS), Washington (CITES), International Plant Protection Convention

(IPPC), and within the framework of the European Commission's activities, deal with biological invasions. During that time, I was the delegate of the Ministry of the Environment for 20 meetings of these bodies (Appendix 6, IIIN) and prepared over 20 expert opinions, assessment and positions presented by Poland at these meetings (Appendix 6, point IIIM). I participated in the work of the CBD Convention in developing definitions of an alien species and invasive alien species. I also took part in preparation of documents that were subsequently adopted as binding decisions of the Conference of the Parties to this Convention. During the Polish presidency of the Council of the European Union in 2011, I was a government expert; my achievements included chairing the member states negotiations on the legal act that was adopted in 2014 as Regulation (EU) No 1143/2014 of the European Parliament and of the Council on invasive alien species. Since 2014, I represent Poland in the Scientific Forum appointed by the European Commission to provide support for the implementation of this Regulation.

I presented the problem of alien species during over 100 hours of lectures for PhD students, students of biology, as well as for postgraduate students (Appendix 6, point III I1). As the major difficulty in effective solutions to the problem of alien species is very poor knowledge on this subject among the general public, I consider raising awareness to be a very important element of my activity.

I disseminated knowledge about alien species in the media, providing about 20 interviews on TV stations (including TVP1, TVP Gdańsk, TVN, TVN24, Polsat News) and radio stations (including PR I, PR III, Radio Kraków, Radio Opole, ToK FM) and about 40 interviews for the press (including PAP, Wprost, Newsweek, Gość Niedzielny, Rzeczpospolita, Gazeta Wyborcza, Gazeta Polska, Polska the Times, National Geographic) and Internet portals (including WP, Interia, Onet, PAN, Nauka w Polsce, Explorers, Farmer). I am also the author of 9 publications popularizing this topic in the press (Appendix 6, point III I2).

I taught several dozen hours of classes on biological invasions, accepting invitations from kindergartens, primary and secondary schools, hospitals and universities for children. Since 2012, every year I have been conducting classes on this subject for children as part of the Science Festival in Kraków (Appendix 6, point III I1). The article of my co-authorship (Najberek and Solarz 2016 P61) was selected as the recommended reading for junior high school students taking part in the biological contest. I also had several dozen presentations on alien species at the invitation of non-governmental organizations and administration of national parks in Poland (Appendix 6, point III I1).

In addition to biological invasions and bird ecology, I am interested in the reasons and consequences of the decline in the number of pollinators, especially bumblebees. I co-authored several papers dealing with this issue (Kosior et al. 2003 P29, 2007 P04, 2008 P08, Palik et al. 2005 P33).

6. Plans for the future

My intention is that biological invasions remain my main field of research, although I am also going to continue studies into ecology of bird populations and threats to pollinators.

My most ambitious long-term goal is to take full advantage of the huge scientific potential that was created thanks to the project on the national strategy on alien species, prepared for GDOŚ in 2018. For many of the participating experts, alien species were only a small part of their professional field. The work on the strategy has facilitated the establishment of cooperation between scientists who previously had not had any opportunity to collaborate. Thanks to the integration of the scientific community (over 100 experts from over 30 institutions), it was possible to develop an unprecedented data set in Poland, including, information on biology of alien species, the history of their introduction, population dynamics, impact on native wildlife, ecosystem services, economy, human health, climate impact and occurrence (almost 600,000 records). These data is an excellent material for comprehensive analyses.

However, the potential of this research team can be even better utilized by taking on new challenges, such as new projects and scientific publications. To this end, I would like to continue to integrate the network of experts dealing with various aspects of biological invasions. I intend to do it thanks to development of the 'Alien species in Poland database', as a part of the project that I applied as a member of a consortium of 18 scientific institutions. I also plan to create a platform for the exchange of information for experts who deal with various aspects of biological invasions. I am convinced that due to the complexity of this problem, it is of key importance for finding synergy and establishing cooperation, and hence for the development of scientific potential.

In the near future, as part of my earlier international cooperation, I intend to continue my research on the threats resulting from the presence of alien species, whose current numbers and range are restricted. During the review and in the final stage of preparation for publishing, there are further papers on the invasiveness of the Balfour's impatiens. I intend to continue research on this species as part of the NCN project, which I applied for in 2018. Prepared for publishing, there is also an article comprehensively analysing the occurrence in Poland of alien animal species that escaped or were released from captivity, as well as on alien bird species in Poland.

Another topic of my research will be the role of habitats strongly transformed by humans in biological invasions. I am particularly interested in thermally polluted waters. The results of my research so far indicate that such places are the invasion centres in Poland.

I will also deal with the sociological aspect of biological invasions. An innovative element in this context will be the problem that I have termed "ecosystem disservice by alien species through landscape pollution". It concerns the large-scale negative impact of widely distributed alien species, which are generally considered non-invasive. In the final stage of preparation for publishing, there is also an article on the perception of the problem of biological invasions by Poles living in the British Isles. Due to the scale of the flow of people and goods related to

this emigration, the results of these studies will be of significant importance both from the perspective of Poland, as well as Great Britain and Ireland.

In 2019, the adoption of the Act on alien species is planned in Poland. In the coming years, this will certainly be associated with new challenges in the field of implementing these provisions. Therefore, as the main author of the national strategy on alien species, I intend to continue my cooperation with the government in implementation of the results of scientific research into practice, as well as in education in this area.

Summary of bibliometric data (status as of 9.04.2019):

- **number of published scientific papers: 66 (including 30 articles from the JRC list)**
- **total Impact Factor (compliant with the year of publication) for all publications: 100.848**
- **total number of citations indexed in the Web of Knowledge database: 1,532 (without self-citations)**
- **Hirsch index (according to Web of Science): 10**
- **total number of MNiSW (Ministry of Science and Higher Education) points: 1044 (including 982 points for publications in journals indexed in JCR).**

References

- Adamowski W. 2009. *Impatiens balfourii* as an emerging invader in Europe. *Neobiota* 8: 183–194.
- Bacher S., Blackburn T.M., Essl F., Genovesi P., Heikkilä J., Jeschke J.M., Jones G., Keller R., Kenis M., Kueffer C., Martinou A.F., Nentwig W., Pergl J., Pyšek P., Rabitsch W., Richardson D.M., Roy H.E., Saul W.C., Scalera R., Vilà M., Wilson J.R.U., Kumschick S. 2018. Socio-economic impact classification of alien taxa (SEICAT). *Methods in Ecology and Evolution* 9: 159-168.
- Beever E.A., Simberloff D., Crowley S.L., Al-Chokhachy R., Jackson H.A., Petersen S.L. 2019. Social–ecological mismatches create conservation challenges in introduced species management. *Front Ecol Environ* doi:10.1002/fee.2000
- Blackburn T.M., Pyšek P., Bacher S., Carlton J.T., Duncan R.P., Jarošík, V., Wilson J.R.U., Richardson D.M., 2011. A proposed unified framework for biological invasions. *Trends Ecol. Evol* 26: 333–339.
- Carlton J.T. 1996. Biological invasions and cryptogenic species. *Ecology* 77: 1653–1655.
- CBD. 2002. COP 6 Decision VI/23: Alien species that threaten ecosystems, habitats or species. Sixth Meeting of the Conference of the Parties to the Convention on Biological Diversity, 7–19 April 2002, The Hague.
- CBD. 2014. Convention on Biological Diversity's Strategic Plan for Biodiversity.
- Chapman J.W., Carlton J.T. 1991. A test of criteria for introduced species: the global invasion by the isopod *Synidotea laevidorsalis* (Miers, 1881). *J Crustac Biol.* 11: 386–400.
- de Wit R., Bouvier T. 2006. 'Everything is everywhere, but, the environment selects'; what did Baas Becking and Beijerinck really say? *Environ Microbiol* 8: 755–758.
- Essl F., Bacher S., Genovesi P., Hulme P.E., Jeschke J.M., Katsanevakis S., Kowarik I., Kühn I., Pyšek P., Rabitsch W., Schindler S., van Kleunen M., Vilà M., Wilson J.R.U., Richardson D.M. Which Taxa Are Alien? Criteria, Applications, and Uncertainties. *BioScience* 68: 496–509.
- Fenchel T., Finlay J.B. 2004. The ubiquity of small species: patterns of local and global diversity. *Bioscience* 54: 777–784.
- Finlay B.J. 2002. Global dispersal of free-living microbialeukaryote species. *Science* 296: 1061–1063.
- GDOŚ 2014. Kodeks dobrych praktyk „Ogrodnictwo wobec roślin inwazyjnych obcego pochodzenia”. Generalna Dyrekcja Ochrony Środowiska, Warszawa. 76 ss.
- Genovesi P., Shine C. 2004. European strategy on invasive alien species: Convention on the Conservation of European Wildlife and Habitats (Bern Convention) (No. 18-137). Council of Europe.
- Goodman S.J., Barton N.H., Swanson G., Abernethy G.K., Pemberton J. 1999. Introgression Through Rare Hybridization: A genetic study oh a hybrid zone between red deer and sika deer (Genus *Cervus*) in Agryll, Scotland. *Genetics* 152: 355-371.

Green A.J. 2015. The importance of waterbirds as an overlooked pathway of invasion for alien species. *Diversity and Distributions* 22: 239–247.

Hawkins C.L., Bacher S., Essl F., Hulme P.E., Jeschke J.M., Kühn I., Charlotte L. Hawkins Sven Bacher Franz Essl Philip E. Hulme Jonathan M. Jeschke Ingolf Kühn Kumschick S., Nentwig W., Pergl J., Pyšek P., Rabitsch W., Richardson D.M., Vilà M., Wilson J.R.U., Genovesi P., Blackburn T.M. 2015. Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distributions*, 21(11), 1360-1363.

Incagnone G., Marrone F., Barone R., Robba L., Naselli-Flores L. 2015. How do freshwater organisms cross the 'dry ocean'? A review on passive dispersal and colonization processes with a special focus on temporary ponds. *Hydrobiologia* 750: 103–123.

Jarić I., Heger T., Monzon F.C., Jeschke J.M., Kowarik I., McConkey K.R., Pyšek P. Sagouis A., Essl F. (2019). Crypticity in Biological Invasions. *Trends in ecology & evolution*.

Jeschke J.M. 2014. General hypotheses in invasion ecology. *Divers. Distrib.* 20:1229–1234. <https://doi.org/10.1016/j.tree.2018.12.008>

Lenda M., Zagalska-Neubauer M., Neubauer G., Skórka P. 2010. Do invasive species undergo metapopulation dynamics? A case study of the invasive Caspian gull, *Larus cachinnans*, in Poland. *Journal of biogeography* 37: 1824-1834.

Lymbery A.J., Morine M., Kanani H.G., Beatty S.J., Morgan D.L. 2014. Co-invaders: the effects of alien parasites on native hosts. *International Journal for Parasitology: Parasites and Wildlife* 3: 171-177.

McDevitt A.D., Edwards C.J., O'Toole P., O'Sullivan P., O'Reilly C., Cardene R.F. 2009. Genetic structure of and hybridization between red (*Cervus elaphus*) and sika (*Cervus nippon*) deer in Ireland. *Mammalian Biology* 74:263-273.

O'Malley M.A. 2007. The nineteenth-century roots of 'everything is everywhere'. *Nat Rev Microbiol* 5: 647–651.

PZŁ 2015. Uchwała 14/2015. Naczelnej Rady Łowieckiej w sprawie przyjęcia zasad selekcji populacyjnej i osobniczej zwierząt łownych w Polsce oraz zasad postępowania przy ocenie zgodności odstrzału.

Reynolds C., Miranda, N.A., Cumming G.S. 2015. The role of waterbirds in the dispersal of aquatic alien and invasive species. *Diversity and Distributions* 21: 744–754.

Reynolds C., Cumming G.S., Vilà M., Green A.J. 2017. Birds as key vectors for the dispersal of some alien species: Further thoughts. *Diversity and Distributions*, 23: 577-580.

Rozporządzenie 2011. Rozporządzenie Ministra Środowiska z 9 września 2011 r., w sprawie listy roślin i zwierząt gatunków obcych, które w przypadku uwolnienia do środowiska przyrodniczego mogą zagrozić gatunkom rodzimym lub siedliskom przyrodniczym. Dz. U. Nr 210 poz. 1260.

Rozporządzenie 2014. Rozporządzenie Parlamentu Europejskiego i Rady (UE) nr 1143/2014 z 22 października 2014 r. w sprawie działań zapobiegawczych i zaradczych w odniesieniu do

wprowadzania i rozprzestrzeniania inwazyjnych gatunków obcych. Official Journal of the European Union 317 (2014): 35-55.

Roy H.E., Rabitsch W., Scalera R., Stewart A., Gallardo B., Genovesi P., Essl F., Adriaens T., Booy O., Branquart E., Brunel S., Copp G.H., Dean H., D'hondt B., Josefsson M., Kenis M., Kettunen M., Linnamagi M., Lucy F., Martinou A., Moore N., Nieto A., Pergl J., Peyton J., Schindler S., Solarz W., Stebbing P.D., Trichkova T., Vanderhoeven S., van Valkenburg J., Zenetos A. 2017. Developing a framework of minimum standards for the risk assessment of alien species. Journal of Applied Ecology. 55: 526-538.

Roy H.E., Bacher S., Essl F., Adriaens T., Aldridge D.C., Bishop J.D.D., Blackburn T.M. Branquart E., Brodie J., Carboneras C., Cottier-Cook E.J., Copp G.H, Dean H.J., Eilenberg J., Gallardo B., Garcia M., García-Berthou E., Genovesi P., Hulme P.E., Kenis M., Kerckhof F., Kettunen M., Minchin D., Nentwig W., Nieto A., Pergl J., Pescott O.L. Peyton J.M., Preda C., Roques A., Rorke S.L., Scalera R., Schindler S., Schönrogge K., Sewell J., Solarz W., Stewart A.J.A., Tricarico E., Vanderhoeven S., van der Velde G., Vilà M., Wood C.A., Zenetos A., Rabitsch W. 2018. Developing a list of invasive alien species likely to threaten biodiversity and ecosystems in the European Union. Global Change Biology: 1–17.DOI: 10.1111/gcb.14527

Roy H.E., Bacher S., Essl F., Adriaens T., Aldridge D.C., Bishop J.D.D., Blackburn T.M. Branquart E., Brodie J., Carboneras C., Cottier-Cook E.J., Copp G.H, Dean H.J., Eilenberg J., Gallardo B., Garcia M., García-Berthou E., Genovesi P., Hulme P.E., Kenis M., Kerckhof F., Kettunen M., Minchin D., Nentwig W., Nieto A., Pergl J., Pescott O.L. Peyton J.M., Preda C., Roques A., Rorke S.L., Scalera R., Schindler S., Schönrogge K., Sewell J., Solarz W., Stewart A.J.A., Tricarico E., Vanderhoeven S., van der Velde G., Vilà M., Wood C.A., Zenetos A., Rabitsch W. 2018. Developing a list of invasive alien species likely to threaten biodiversity and ecosystems in the European Union. Global Change Biology: 1–17.DOI: 10.1111/gcb.14527

Senn H.V., Pemberton J.M.. 2009.Variable extent of hybridisation between invasive sika (*Cervus nippon*) and native red deer (*C. elaphus*) in a small geographical area. Molecular Ecology 18: 862–876.

Schierenbeck K. 2011. Hybridization and introgression. W: Encyclopedia of Biological Invasions. Simberloff D., Rejmanek M. (red.). University of California Press, Berkeley and Los Angeles, California. ss. 342–346.

Simberloff D. 2012. Nature, natives, nativism, and management: worldviews underlying controversies in invasion biology. Environmental Ethics 34: 5-25.

Solarz W., Okarma H. 2014. Program zarządzania populacją jelenia sika *Cervus nippon* na terenie Polski. Ekspertyza dla Generalnej Dyrekcji Ochrony Środowiska. 78 ss.

Solarz W., Mazurska K., Dajdok Z., Król W., Najberek K., Olszańska A., Urbisz A., Zarychta A., Krzysztofiak A., Krzysztofiak L., Okarma H., Tokarska-Guzik B. 2018. Strategia na rzecz zwalczania inwazyjnych gatunków obcych w Polsce. Ekspertyza dla Generalnej Dyrekcji Ochrony Środowiska. 180 ss.

Stoyneva M.P. 2016. Allochthonous planktonic algae recorded during the last 25 years in Bulgaria and their possible dispersal agents. Hydrobiologia 764: 53–64.

Tokarska-Guzik B., Dajdok Z., Zając M., Zając A., Urbisz A., Danielewicz W., Hołdyński C. 2012. Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych. Generalna Dyrekcja Ochrony Środowiska, Warszawa. 197 ss.

Ustawa z dnia 16 kwietnia 2004 r. o ochronie przyrody (Dz. U. z 2018 r. poz. 142, z późn. zm.).

Walther G.R., Roques A., Hulme P.E., Sykes M.T., Pyšek P., Settele J., Bacher S., Botta-Dukát Z., Bugmann H., Czúcz B., Dauber J., Hickler T., Jarosik V., Kenis M, Klotz S., Kühn I., Minchin D., Moora M., Nentwig W., Ott J., Panov V., Reineking B., Robinet C., Semenchenko V., Solarz W., Thuiller W., Vilà M., Vohland K., Zobel M. 2009. Alien species in a warmer world – risks and opportunities. *Trends in Ecology and Evolution*: 24: 686-693.

Zenetos A., Çinar M.E., Crocetta F., Golani D., Rosso A., Servello G., Shenkar N., Turon X., Verlaque M. 2017. Uncertainties and validation of alien species catalogues: The Mediterranean as an example. *Estuarine, Coastal and Shelf Science* 191: 171-187.

Kraków, 9.04.2019



Wojciech Solarz