Autoreferat

1. Name.

   Łukasz Jermacz

2. Diplomas, degrees conferred in specific areas of science or arts, including the name of the institution which conferred the degree, year of degree conferment, title of the Ph.D. dissertation

   - 2012 - Master's degree in "Environmental Protection" from the Nicolaus Copernicus University in Torun, Faculty of Biology and Earth Sciences (currently Faculty of Biological and Veterinary Sciences). Master's thesis entitled "The influence of racer goby *Babka gymnotrachelus* on the feeding efficiency of the European bullhead *Cottus gobio*", carried out in the Department of Hydrobiology (now a part of the Department of Ecology and Biogeography). Supervisor: dr hab. Andrzej Kentzer prof. NCU.

   - 2017 – Ph.D. obtained at the Nicolaus Copernicus University in Torun, Faculty of Biology and Environmental Protection (currently the Faculty of Biological and Veterinary Sciences). Ph.D. thesis titled "Habitat preferences of two alien species, *Pontogammarus robustoides* and *Dikerogammarus villosus* (Crustacea, Amphipoda), carried out in the Department of Invertebrate Zoology (now the Department of Invertebrate Zoology and Parasitology) graduated with distinction. Supervisor: prof. dr hab. Jarosław Kobak. Auxiliary supervisor: dr hab. Małgorzata Poznańska-Kakareko prof. UMK. Reviewers: prof. dr hab. Ryszard Kornijów and prof. dr hab. Michał Grabowski.

3. Information on employment in research institutes or faculties/departments or school of arts.

   - 01.03.2017-31.12.2017 research assistant at the Nicolaus Copernicus University, Department of Invertebrate Zoology,
   - from 01.01.2018 assistant professor at the Nicolaus Copernicus University in Torun, Department of Ecology and Biogeography
   - 15.10.2019-15.12.2019 post-doc fellowship in Balaton Limnological Research Institute (Hungary). The duration of the stay was limited due to epidemic restrictions.

4. Description of the achievements, set out in art. 219 para 1 point 2 of the Act

A series of publications from 2017-2022, under the common title: "**Ecology of fear - behavioural and physiological modifications induced by the presence of a predator**".

1) **Jermacz Ł**, Kobak J. 2017. Keep calm and don't stop growing: Non-consumptive effects of a sympatric predator on two invasive Ponto-Caspian gammarids *Dikerogammarus villosus* and *Pontogammarus robustoides*. PLoS One. 12(8):e0182481. doi: 10.1371/journal.pone.0182481.

   According to the Web of Science for the year of publication Q1, Impact Factor: 2.766; citations: 15 (8 excluding self-citations), MNiSW points from the year of publication: 35.

   Contribution: Concept and methodology of work, carrying out experiments, analysis of the results, preparation and submitting the manuscript, obtaining financing

2) **Jermacz Ł**, Nowakowska A, Kletkiewicz H, Kobak J. 2020. Experimental evidence for the adaptive response of aquatic invertebrates to chronic predation risk. Oecologia. 192(2):341–350. doi: 10.1007/s00442-020-04594-z.

   According to the Web of Science for the year of publication Q2, Impact Factor: 3.225; citations: 11 (7 excluding self-citations), MNiSW points from the year of publication 100.

   Contribution: Concept and methodology of work, carrying out experiments, analysis of the results, preparation and submitting the manuscript, obtaining financing

3) **Jermacz Ł**, Kletkiewicz H, Poznańska-Kakareko M, Klimiuk M, Kobak J. 2021. Chronic predation risk affects prey escape abilities through behavioral and physiological changes. Behav Ecol. 33(1): 298-306. doi: 10.1093/beheco/arab142.

   According to the Web of Science for the year of publication Q1, Impact Factor: 3.087; citations: 0, MNiSW points from the year of publication 140.

Contribution: Concept and methodology of work, carrying out experiments, analysis of the results, preparation and submitting the manuscript, obtaining financing

4) **Jermacz Ł**, Kletkiewicz H, Krzyżyńska K, Klimiuk M, Kobak J. 2020. Does global warming intensify cost of antipredator reaction? A case study of freshwater amphipods. Sci Total Environ. 742:140474. doi: 10.1016/j.scitotenv.2020.140474.

   According to the Web of Science for the year of publication Q1, Impact Factor: 7.963; citations: 6 (3 excluding self-citations), MNiSW points from the year of publication 200.

   Contribution: Concept and methodology of work, carrying out experiments, analysis of the results, preparation and submitting the manuscript, obtaining financing.

Total Impact Factor from the year of publication 17,041; MNiSW score 475, number of citations (18 excluding self-citations). In all publications, I was the first and corresponding author. All the above research are result of the projects financed by the Polish National Science Centre 2016/21/B/NZ8/00418, „Ecology of fear of invasive organisms. Are Ponto-Caspian gammarids (Crustacea, Amphipoda) less susceptible to predator-induced stress?"). The project started before obtaining the doctoral degree, but the results obtained during the implementation of the tasks set out in this project were not used in the doctoral dissertation.

Introduction

Predation is a fundamental factor that shapes the evolution of organisms, structures of communities, functioning of ecosystems, and rate of population changes (Krebs et al. 1995; Peckarsky et al. 2008; Schmitz 2008). Predators control prey populations by eliminating the least adapted, sick or wounded individuals. A reduction of prey density due to direct predation is called the consumptive predator effect. Predatory species also affect prey by inducing costly defensive responses, causing a reduction in growth and/or population size (Lima 1998; Peckarsky et al. 2008; Clinchy et al. 2013). These costly risk reduction changes are manifested in modifications of behaviour, physiology, morphology, or life history of prey (Lima 1998; Werner and Peacor 2003; Sheriff and Love 2013). Predator impact does not result in direct death of prey, but causes costly modifications, is called the non-consumptive predator effect. The non-consumptive (indirect) predator effect results from the many costly reactions that prey exhibit to reduce predation risk, including reduced

foraging, investment of energy in morphological defence structures and emigration from the endangered area. A meta-analysis comparing consumptive and non-consumptive predator effects indicates that the effect of indirect predator pressure is comparable with that of direct predation` (Preisser et al. 2005). Ecologists are paying more and more attention to the indirect influence of a predator, but, despite its importance, it is a largely undiscovered area of science. The issue of the indirect effect of a predator is extremely complex, and the costs borne by the prey as a result of this type of impact depend on many factors, including the time of exposure to the predator, the presence of hiding places, the availability of food, the abundance of predators and their hunting strategy, the presence of individuals of their species, abiotic factors (e.g. temperature), etc. Each of these factors separately shapes the prey response, and interact with the others. Therefore, the assessment of the indirect impact of a predator, despite the growing knowledge and technological development, is a significant challenge for modern researchers.

A very poorly understood issue is the indirect effect of local predators on prey of alien origin and the status of invasive species. The native predator pressure (also the indirect one) may reduce the ability of alien species to create fully functional populations in an invaded area. Resistance to the indirect influence of a predator and to related costs may facilitate functioning in a new environment (Naddafi and Rudstam 2013). The desire to deepen the knowledge about the costs of defence mechanisms borne by alien species was the reason for undertaking the research presented in my habilitation thesis. As a research model, I chose three species of aquatic invertebrates - gammarids (Amphipoda, Crustacea), characterized by different invasive potentials and different defence abilities. The first, *Dikerogammarus villosus* (Sovinsky, 1894), represents the Ponto-Caspian fauna that has been successfully occupying new areas in central and western Europe for decades. The selected species shows a significant invasive potential, mainly due to omnivorousness with a tendency to consume food of animal origin, low habitat requirements and, as shown by experimental studies, relatively effective avoidance of predator pressure (also from unknown species found in newly inhabited areas) (Kobak et al. 2014; Błońska et al. 2015, 2016). The second studied species was *Pontogammarus robustoides* (G.O. Sars, 1894), another Ponto-Caspian species currently expanding its range in Europe, but with a lower level of invasiveness than *D. villosus*, and lower survival in the presence of a predator (Kobak et al. 2014). The last species selected for the study, showing the lowest invasive potential, was *Gammarus jazdzewskii*, a common native species in Central Europe, recently separated from the species *Gammarus fossarum* (Rudolph et al. 2018). This species,

compared to its invasive counterparts, is characterized by smaller body size, softer exoskeleton and higher mortality caused by direct predator pressure under experimental conditions (Kobak et al. 2014; Błońska et al. 2015, 2016). In the conducted experiments, I used two fish species as predators: the racer goby (*Babka gymnotrachelus*) - a Ponto-Caspian species, native to the same region as the invasive gammarids, and the Eurasian perch (*Perca fluviatilis*), a species common in the locations where native and invasive gammarids occur. During my experimental studies, I conducted behavioural and physiological observations to obtain a comprehensive picture of the responses of the selected species to predation risk. The selected invertebrates were tested in various combinations, as well as under various environmental conditions, depending on the particular research hypothesis.

Research objective

The conducted experiments aimed to analyse the indirect influence of a predator on the functioning of prey and to assess the costs of defence reactions, considering the prey invasiveness, exposure time (comparison of the short-term reaction with the chronic one) and abiotic factors, e.g. thermal conditions (determination of the influence of global warming on interactions between predators and prey).

The main research hypothesis was as follows: alien species with a high invasive potential show increased resistance to indirect predator influence, which is manifested in lower behavioural and physiological costs of defence reactions, as well as in a lower level of physiological stress induced by the presence of a predator.

Detailed hypotheses

1. The presence of a predator leads to the modification of the prey behaviour, including a reduction in activity and an increase in the time of shelter use.
2. In the presence of a predator, prey modifies its metabolic rate to increase the effectiveness of its behavioural defence reactions.
3. The behavioural and physiological changes induced by the presence of a predator generate costs as a result of reduced food intake and investment of energy resources into cellular defence mechanisms, such as antioxidant defence and heat shock proteins.

4. The consequences of the reactions induced by the presence of a predator are: oxidative stress (a side effect of the increased metabolic rate), reduced amount of reserve materials (glycogen) and/or slower growth.
5. Under a prolonged exposure to the predator presence (chronic predator effect), prey reduces the level of resources invested in cellular defence mechanisms against oxidative stress, compared to the short-term predator effect.
6. The behavioural and physiological consequences of exposure to a predator are species-specific and correlated with the invasive potential of each species.
7. Increasing temperature increases the cost of predator-induced defence reactions and may increase the advantage of invasive species over native ones as a result of global warming.

Results

To verify the hypotheses, I conducted a series of experimental studies with my research team, during which we manipulated the period of exposure to the presence of a predator, thermal conditions and the availability of food. In response to the threat, the prey modify many aspects of their biology, therefore, during or after the exposure, I monitored behavioural changes, such as activity, time spent in the shelter, amount of food eaten, swimming speed, as well as physiological parameters: metabolic rate, oxidative stress, antioxidant defence, amount of accumulated reserve material (glycogen), anaerobic metabolism (lactate concentration).

The main goal of the experiments presented in publication no. 1 was to determine the behavioural response related to food intake by two species of invasive gammarids (*D. villosus* and *P. robustoides*) to the threat resulting from the presence of a predator, including the impact of these changes on their growth. For this purpose, for 2 hours, I observed the amount of food eaten and the rate of food consumption by single individuals under controlled conditions and in the presence of the predator's kairomone. The obtained results showed that if the food is within the direct reach of the prey then, despite the presence of a predator's signal, food is taken up by both gammarid species similar to the control conditions. In next step, I determined the long-term influence of the predator on gammarid growth. Previous studies have suggested that in the presence of a predator, prey modifies a number of physiological processes, reducing the amount of energy invested in growth (even when food intake remains undisturbed) (Stoks 2001; McPeek 2004). To verify the influence

of the long-term presence of a predator on the growth of prey, single individuals of each species were kept for two weeks under control conditions or in the presence of the predator (racer goby). During the exposure period, the predator had no possibility of physical contact with the tested individuals but it was regularly fed with gammarids of a given species to simulate a high threat. During the experiment, gammarids were fed ad libitum. Despite the unrestricted access to food in the small area that corresponded to the conditions of the previous experiment, *P. robustoides* showed a significant reduction in growth rate in the presence of a predator. On the other hand, *D. villosus* specimens kept in the presence of a predator did not differ in growth from specimens from control conditions. Taking into account the previous results (lack of negative impact of predation risk on food consumption), it can be concluded that other mechansims than behavioural changes were responsible for the observed reduction in the growth of *P. robustoides*.

therefore, the results of publication number 1, suggest that changes in the physiology of gammarids induced by predation risk can be responsible for the reduction in their growth rate. In the study presented in publication number 2, I decided to explore this aspect of their defence response. Under predation risk, prey may modify many aspects of their physiology. Some of these changes directly increase the effectiveness of a defensive reaction, such as the increase in the metabolic rate, raising the efficiency of muscles necessary for escape or direct defence (Glazier et al. 2020). In the presence of a predator, prey may also modify their physiology not directly to increase their safety, but to compensate for the costs of defence reactions. For example, in conditions of limited feeding, prey may increase the efficiency of nutrient uptake (Thaler et al. 2012). The above-mentioned physiological changes, despite having a positive effect on prey survival, are also associated with specific consequences. For example, an increase in metabolism consumes significant amounts of energy resources and is associated with an increased synthesis of harmful reactive oxygen species, responsible for oxidative damage of cell structures, impairing their functionality. To reduce the negative impact of reactive oxygen species, an organism is forced to make additional investments of available energy resources in costly antioxidant defence. Accordingly, a long-term increased metabolic rate can lead to exhaustion. Alternatively, prey may show habituation to the stress factor, which will protect them from the negative consequences of a long-term defence response. In publication 2, *D. villosus* and *G. jazdzewskii* were exposed to the predator signal for three time periods (30 minutes, 24 hours and 7 days) to detect long-term changes in physiology and/or to detect habituation to the stress factor. The obtained results indicate a number of physiological changes induced by

the presence of a predator (increased metabolic rate, activation of antioxidant defence, synthesis of heat shock proteins) and their dependence on the exposure time and species of prey. I have shown that in the case of the native species (*G. jazdzewskii*), despite the investment of resources in cellular defence mechanisms, a short-term response induced by the presence of a predator resulted in oxidative damage. Along with the prolongation of the exposure to predation risk, *G. jazdzewskii* limited the costly antioxidant defence though still maintaining an elevated metabolic rate. Contrary to the native species, the short-term reaction of invasive *D. villosus* was not related to the investment of resources into cellular defence mechanisms, and yet it did not result in oxidative damage, suggesting a greater tolerance of this species to the indirect influence of the predator. The differences in the cost-consumption of predator-induced defence mechanisms can be accounted for by different defence strategies used by both species. Compared to the native species, *D. villosus* is larger and has a harder exoskeleton (Błońska et al. 2015). Moreover, experimental studies showed that this species exhibited a higher survival rate in the presence of various predators than other gammarids, including *G. jazdzewskii* (Kobak et al. 2014; Błońska et al. 2015, 2016). Probably due to the relatively highly developed constitutive defence, *D. villosus* may invest less resources into physiological changes associated with the induced defence response than the native species.

The results presented in publication 2 indicate that the costs resulting from the presence of a predator depend on the exposure time, and also differ between the species of prey, but there is no information on how a long-term exposure to a predator affects the defensive abilities of the studied species. Determining the consequences of the long-term exposure in the presence of a predator on the locomotor abilities of gammarids was the main goal of publication number 3. Previous studies have shown that prolonged predator pressure can result in both an increase in the ability to defend (Hawlena et al. 2011), as well as in its reduction (Janssens and Stoks 2014). To determine how a long-term predatory pressure may affect the defence reactions of the studied species, *D. villosus* and *G. jazdzewskii* individuals were divided into groups that differed in the exposure period in the presence of a predator (control group - without the presence of a predator, group stimulated briefly, group stimulated chronically). After exposure, the gammarids were subject to an exercise test verifying their locomotor performance. Content of lactate (anaerobic metabolism proxy) and glycogen (reserve material) in gammarid body were also measured. The obtained results showed that after a short-term exposure in the presence of a predator, locomotor activity was associated with exceeding the capacity of oxygen metabolism, as indicated by an

increase in the level of lactate, and, in the case of the native species, also with behavioural symptoms of fatigue. When previously exposed to a predator for a long time, the invasive species showed lower levels of lactate after the exercise test compared to the shortly pre-exposed group. This suggests that after chronic exposure, the invasive species is better prepared to undertake physical effort, which may determine the effectiveness of its defence response. I have not noticed such a physiological change in the native species, which may indicate its weaker adaptation to functioning in conditions of chronic predator pressure. In addition, I found that individuals of both species stimulated by a predator signal for a long time showed a decreased level of glycogen, indicating an increased energy expenditure during the exposure.

Temperature is a fundamental factor shaping the physiology and behaviour of organisms, especially of ectothermic species. Thermal conditions determine the rate of their metabolism, as well as the maximum amount of energy that the prey can invest in its defensive reaction. Therefore, progressing global climate change is a factor that significantly affects the functioning of ecosystems and occurrence range of many organisms, potentially promoting biological invasions. As a part of publication number 4, I conducted research aimed to determine the interaction between thermal conditions and the physiological and behavioural changes induced by the presence of a predator in *D. villosus* and *G. jazdzewskii*. These species evolved in areas with different thermal conditions. Moreover, in Europe they currently occupy locations with different thermal properties. Therefore, I expected that the invasive species would prefer a higher temperature and would be better adapted to the progressing climate change. In the experiment, three temperature values were used, which corresponded to the average annual temperature (10 °C), the average temperature of the warmer half of the year (17 °C) and the average temperature of the warmest month (24 °C) in the Vistula River (Marszelewski i Pius 2014, 2016). The obtained results indicate that temperature significantly modifies physiological reactions induced by the presence of a predator. Stimulation by predator kairomones increased the level of oxidative damage only in the native species and only at extreme temperatures (10 °C and 24 °C). Moreover, at 17 °C, both species showed the highest locomotor activity, which indicates that among the tested thermal ranges, 17 °C is the optimal value, as both species showed the highest body performance. With temperature increase the tested species showed an increase in the level of antioxidant defence (Total Antioxidant Status - TAS). Higher levels of TAS mean a greater ability to defend against the negative consequences of increased metabolism but maintaining such a high intensity of antioxidant defence involves

significant energy resources. One of the alternative ways to limit the synthesis of free radicals is to reduce locomotor activity. Compared to the intermediate temperature, the locomotor activity of the examined gammarids at 24 °C was significantly lower, indicating the behavioural response as a mechanism limiting the synthesis of free radicals and the related costs incurred by the organism. In summary, both the increase in temperature and the presence of predator result in the increased metabolic rate. In addition, as the temperature rises, the level of resources invested in antioxidant defence increases, and when the tolerance threshold is exceeded, a reduction in locomotor activity takes place, which helps to avoid oxidative damage. In suboptimal conditions (temperature lower or higher than the optimum), the presence of a predator leads to the oxidative damage in the case of native species. Thus, negative effects of stress are only visible in the presence of both stress factors at the same time. Increased cost of defence reaction of native species shows the actual consequences of progressive global warming, while at the same time pointing to a better adaptation of the alien species to function under altered thermal conditions.

The significance of the obtained research results

The presented set of experimental studies significantly broadens the scope of knowledge about the functioning of prey under the risk of predators. My experiments showed that despite undisturbed food intake, long-term predator pressure may be associated with a reduction in the growth rate of prey, suggesting increased costs of functioning in risky conditions (*P. robustoides*). However, this phenomenon was not observed in *D. villosus*, indicating a higher resistance of this species to the negative effects of the indirect predator influence. Increased costs of functioning may result from an increase in metabolic rate and related physiological responses. My subsequent research has shown that in the presence of a predator, prey (*D. villosus* and *G. jazdzewskii*) accelerate their metabolic rate, which in the case of the native species leads to oxidative damage despite the investment of available resources into the antioxidant defence. Investing energy into protection against the negative effects of reactive oxygen species is a short-term phenomenon, indicating the ability of prey to reduce the cost of physiological modifications associated with the long-term indirect predator impact. Despite the reduction in the level of antioxidant defence during the prolonged exposure to the presence of a predator and the lack of influence of the predator kairomone on food consumption, prey (*D. villosus and G. jazdzewskii*) show a reduced amount of the reserve material (glycogen). Contrary to the native *G. jazdzewskii*, *D. villosus* exposed to the presence of a predator for a lomg time shows an increase in the effectiveness

of its defence reaction (increase in the capacity of oxygen metabolism). My research has also shown a significant effect of global warming on predator-prey interaction. The significant influence of suboptimal temperatures is particularly noticeable in the case of the native species, which in the presence of a predator suffers oxidative damage under unfavourable thermal conditions. Summing up, the performed experimental studies show the great importance of the indirect influence of the predator on the prey, at the same time indicating that the consequences of changes induced by the presence of the predator are species-specific and dependent on abiotic environmental conditions. Among the studied species, *D. villosus*, one of the most effective invasive aquatic species, showed the highest ability to function in conditions of chronic predator influence. This feature may be one of the basic factors facilitating its spread, especially in ecosystems exposed to the effects of global warming.

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5. Presentation of significant scientific or artistic activity carried out at more than one university, scientific or cultural institution, especially at foreign institutions.

In the period 15/10/2019 - 15/12/2019, I did a postdoctoral fellowship at the Balaton Limnological Research Institute (Tihany, Hungary) - my entire stay was planned for 6 months, but, due to the pandemic, the possibility of continuing research by people from other countries in the Hungarian centre has been limited. During my stay, together with Dr. Csilla Balogh, we studied the issues related to the interactions between the invasive bivalves: *Dreissena polymorpha* and *Dreissena rostriformis bugensis*. The former has been present in European waters since the beginning of the 19th century, while the latter is a newcomer, effectively driving out a competitor. Our research was aimed at identifying the behavioural differences and interspecies interactions between them, as well as identifying the mechanisms of displacement of one species by another. Laboratory and field experiments were carried out, and the obtained results were correlated with previous long-term field observations. Despite the difficulties related to the lack of my physical presence in the Hungarian centre in the later period of the planned research, the cooperation is being continued, and its first effect is our common publication: Jermacz, Ł. Balogh, C. & Kobak, J. (2021). Behavioural differences and interactions between two sessile bivalves forming mixed-species assemblages. Animal Behaviour 171: 13-28. Subsequent publications are being prepared for the submissions. My stay was financed under the project GINOP-2.3.2-15-2016-00019 "Sustainable use of ecosystem services - research for mitigating the negative effect of climate change, land use change and biological invasion", led by Dr. András Báldi. An element of the continuation of cooperation was also my two-week stay at the Balaton Limnological Research Institute in September 2022, during which, together with local researchers, we continued the previously started research.

My research activity is also focused on cooperation with other foreign centres. Currently, I am the head of the project entitled "The impact of global warming on the interaction between indigenous and foreign ectothermic species of prey and predators", financed by the National Science Center. The tasks set out in the project are carried out in cooperation with Professor Douglas Glazier from Juniata College, Huntingdon,

Pennsylvania, USA, a recognized specialist in the field of research on metabolic rate of ectothermic species.

In addition to the above-mentioned foreign institutions, I actively cooperate with researchers from the University of Lodz, Poland. Currently, I am acting as an investigator in the National Science Center project (implementation years: 2019-2023): "Can bad things become worse? Experimental assessment of the success of two genetically differentiated fronts of the crustacean invasion of *Dikerogammarus villosus* and the possibility of the formation of a superhybrid with a higher invasive potential", led by Dr. Tomasz Rewicz. I was also an investigator in the National Science Center project (2012-2017): Testing the "invasional meltdown" hypothesis on the example of the group of invasive Po-Caspian species in Polish inland waters", led by Dr. Karolina Bącela-Spychalska, prof. UŁ. The research was aimed at determining the network of interactions between invasive species from the Ponto-Caspian region occurring in Polish waters and determining whether the phenomenon of increasing the invasive potential (efficiency of introduction and impact strength) of some species by another (the "invasional meltdown" hypothesis) occurs in this group. Publications from the above project with my participation: items 4, 13 in part A and item 6 in part B of point II of Annex 4.

6. Presentation of teaching and organizational achievements as well as achievements in popularization of science or art.

So far, I have conducted classes for students of Environmental Protection, Biology, Forensic Biology, and Global Change Biology in the following subjects:

- Freshwater biology
- Identification and biology of invasive animal species
- Blood-sucking arthropods in the context of public health protection in Poland (coordinator)
- Introduction to ecology
- Bioindicators
- Ecosystem Functioning - subject in English
- Biological invasions (for students of Biology)
- Restoration of the environment

- Methods for analyzing aquatic environments
- Invasive species and environmental threats
- Introduction to underwater research with the use of scuba diving (coordinator)
- Chemical analytical methods in environmental research (coordinator)
- Protection and rehabilitation of water and soil
- Valorization and monitoring of the environment
- European directives in the protection of the environment
- Water ecosystems - diversity and functioning
- Environmental management systems in production plants
- Global changes, civilization threats and sustainable development
- Assessment of the degree of conservation of habitats and plant species in terms of the Habitat Directive

In addition, I am a co-author of a monographic lecture for students of the Doctoral School of Exact and Natural Sciences at the Nicolaus Copernicus University in Toruń "Biological invasions".

In the years 2016-2021 I was an auxiliary supervisor in the doctoral thesis of Anna Dzierżyńska-Białończyk (main supervisor, Prof. Jarosław Kobak). The doctoral dissertation "Factors influencing locomotor activity, distribution and movement of clam shells *Dreissena polymorpha* (Pallas, 1771)" by Anna Dzierżyńska-Białończyk was defended with honours in 2021. Since 2019, I am an auxiliary supervisor in the doctoral dissertations of Piotr Kłosiński and Mateusz Augustyniak. In both cases, the main supervisor is dr. hab. Tomasz Kakareko, prof. UMK.

Organizational achievements:

- Since 2020, I have been a member of the Council of Scienticic Discipline of Biological Sciences at the Faculty of Biological and Veterinary Sciences as a representative of academic teachers who do not hold a postdoctoral degree.
- Since 2021 I have been a tutor for the students of "Global change biology" study programme
- In 2018, I was a co-organizer of XXXIV National Malacological Seminar (Torun).

Achievements in popularizing science:

- After obtaining my doctoral degree, I was a co-organizer of a popular science event "The Night of Biologists" at my faculty twice (2018 and 2019).
- I participated in the creation of an episode related to invasive species, being a part of the "Meeting with ecology" tv programme, broadcasted on local television.

Apart from information set out in 1-6 above, the applicant may include other information about his/her professional career, which he/she deems important.

My first contact with scientific activity took place during my master's thesis study (2010-2012), financed by the Ministry of Science and Higher Education within project No. N N304 371539, "The influence of an alien species of fish, the racer goby (*Neogobius gymnotrachelus*), on the occurrence of the European bullhead (*Cottus gobio*)", led by my supervisor dr. hab. Tomasz Kakareko, prof. UMK. During this period I met other team members: prof. dr hab. Jarosław Kobak and dr hab. Małgorzata Poznańska-Kakareko, prof. UMK. Collaborating with experienced scientists who shared their knowledge and experience with great dedication, I had the opportunity to acquire basic and key skills necessary for scientific work. My commitment resulted in entrusting me with the continuation of research on the interactions between the racer goby and bullhead during the absence of the principal investigator (due to his scientific leave abroad). The result was my first publication as the first author: Jermacz et al. 2015 (Annex No. 4, point II, part A, item No. 7). During the implementation of the above project, I also had the opportunity to get to know and gain knowledge and experience from scientists from outside my home university, such as professor Gordon H. Copp from CEFAS, Centre for Environment Fisheries and Aquacultrure Science, United Kingdom, or dr hab. Joanna Grabowska, prof. of the University of Lodz, with whom we jointly published the results obtained under the project (Annex 4, point II, part A, items 1, 11 and 12).

As a beginning scientist, fascinated by broadening my knowledge, and wanting to develop further, in 2012 I decided to start doctoral studies at the Faculty of Biology and Environmental Protection of the Nicolaus Copernicus University under the supervision of Professor Jarosław Kobak. At the same time, I was awarded the position of an investigator in the NCN OPUS project no. 2012/05 / B / NZ8 / 00479, "Habitat preferences of Ponto-Caspian bream species (Crustacea, Amphipoda), invasive in

European waters". The subject of my doctoral thesis concerned the habitat preferences of the invasive amphipods *D. villosus* and *P. robustoides*, taking into account the role of a predator, which later became the dominant aspect of my scientific interest. Closer cooperation with professor Kobak was extremely important for me for my development. It was thanks to professor Kobak that I learned the secrets of experimental research and mastered the basic tools related to statistical analysis. During my work on my PhD thesis (2012-2017), I was also involved in the implementation of a project led by dr. hab. Karolina Bącela-Spychalska from the University of Lodz, whose aim was to verify the "Invasional meltdown" hypothesis on the example of Ponto-Caspian alien species.
Thanks to the lessons received from the supervisor and the experience gathered from other scientists, in 2014 I received funding for my first research project (NCN PRELUDIUM, No. 2013/09 / N / NZ8 / 03191, "Experimental evaluation of defence mechanisms induced by predators in selected species of invasive Ponto-Caspian sprouts) "). I consider the skills acquired in the process of creating the application to be extremely valuable and key in the further steps of my career. During this project, for the first time, I was able to fully focus on predator-prey interaction, which has become my main research interest until now. Work on the preferred subject turned out to be very fruitful, as the project was completed with a collection of articles in reputable journals (Annex 4, point II, part A, items: 5, 13, 14, 16). These articles then became parts of my doctoral dissertation. The implementation of a relatively small project dedicated to young scientists showed me how important it is to receive financial support from external institutions, without which it would be much more difficult to carry out research at a level guaranteeing the interest of the international scientific community. The experience gathered during this period allowed me to successfully continue my scientific career as an independent researcher, acquiring funds for research, managing research teams and cooperating with scientists from various countries, institutions and fields of knowledge.

Willing to continue my scientific career (at that time there was no possibility of employment in my parent institution) and the research, I decided to apply for another project at the National Science Center under the OPUS competition, in which I planned my self-employment. As a result of the above efforts, in 2017 (before obtaining the doctoral degree) I obtained funding for project No. 2016/21 / B / NZ8 / 00418, "Ecology of fear of invasive species. Are Ponto-Caspian sprouts (Crustacea, Amhipoda) less susceptible to stress induced by the presence of predators? " I obtained self-employment

at a scientific institution, which opened the way for further development after defending my doctoral dissertation. The implementation of this project was important for me not only due to the publications (Annex 4, point I, items: 2, 3, 4; point II, part B, item 7), but also due to the process of self-improvement and broadening my scientific horizons. During the implementation of the above project under my supervision, Dr. Katarzyna Krzyżyńska completed her postdoctoral internship. The tasks carried out within the projects I managed allowed me to gain experience in managing research teams and in cooperation with researchers from other institutions and representing other research specialities. Currently, I am managing my next project, NCN SONATA 2020/39 / D / NZ8 / 01226 "The impact of global warming on the interaction between native and foreign ectothermic species of prey and predators", which is an extension of the current research process. The achievements to date and involvement in scientific research have been noticed by, among others, prof. dr. hab. Krzysztof Szpila, who invited me to the "Ecology and Biodiversity" research team he has been managing, financed by the Nicolaus Copernicus University from the funds of the "Initiative of Excellence - Research University" project. The main task of the team is to understand the processes influencing the distribution and abundance of organisms on various spatial and temporal scales. This project is aimed at establishing emerging research fields within the Nicolaus Copernicus University, characterized by particularly outstanding scientific potential and a significant development perspective.

In addition to the above-mentioned projects, my scientific commitment is also noticeable in cooperation with other scientists from my institution. It should be mentioned here, inter alia, dr. hab. Małgorzata Poznańska-Kakareko, prof. NCU, dealing with the responses of invertebrate fauna to fluctuations in water level and related substrate drying. In addition, I support dr. hab. Małgorzata Poznańska-Kakareko in her current research on interactions between native and invasive species of bivalve molluscs. Our joint publication output on the above-mentioned topics includes items 9, 10, 18 in part A and item 9 in part B of point II of Annex 4.

Another person with whom I have recently started cooperation is Dr. Magdalena Czarnecka. Together with Dr. Czarnecka, we are investigating the effect of light pollution on the functioning of communities in coastal waters. Despite the relatively short period of cooperation, we have already published the first result of our research, showing a significant impact of artificial night lighting on the efficiency of predator

feeding on aquatic invertebrates (item number 3 and 12 in part B, point II of Annex 4), and further works are under preparation.

The skills I acquired during cooperation with experienced researchers resulted in establishing cooperation with scientists not directly related to the previously presented hydrobiological research team. For example, since 2021, I have been conducting research with Dr. Anna Stanicka from the Department of Invertebrate Zoology and Parasitology at the Nicolaus Copernicus University to verify the impact of invasive and native invertebrate species on the dynamics of interactions between parasites and their hosts. These organisms can cause the so-called dilution effect, reducing the parasite infection, through predation against free-living life stages of parasites or acting as "dead-end hosts", making it difficult for the larvae to penetrate their target hosts. The collaboration is going to involve several experiments, the results of the first of which have already been published (item 10, part B, point II, appendix 4). I am also involved in biomedical research conducted by Dr. Hanna Kletkiewicz (Department of Animal Physiology and Neurobiology, NCU). Together with Dr. Kletkiewicz, we verified the influence of thermal conditions during perinatal hypoxia on physiological changes in a vertebrate brain (item 5, part B, point II, appendix 4).

In addition to the basic research described above, I also dealt with the practical aspects of the functioning of freshwater fauna, related to the fouling of technical devices and living organisms by sessile animals. In fresh waters, the main invasive species involved in this phenomenon is the zebra mussel, *Dreissena polymorpha* which can effectively inhibit various hydrotechnical applainces, generating significant economic losses. Research on the biology of this mussel and its fouling of various substrates were financed under the NCBiR grant - POIR.01.01.01-00-1043/15-00 "Development of a technology for the production of a nanostructured surface layer with superhydrophobic properties for use in industrial water filters resistant to for biological fouling "(led by CIM-mes Projekt Sp. z o.o. from Warsaw), the GINOP-2.3.2-15-2016-00019 project" Sustainable use of ecosystem services - research for mitigating the negative effect of climate change, land use change and biological invasion "(conducted in cooperation with the Balaton Limnological Research Institute - described above), NCN PRELUDIUM grant no. 2015/17/N/NZ8/01653," The influence of environmental factors on the rhythm of opening and closing the shells by the zebra mussel *Dreissen polymorpha*. "(head: Dr. Anna Dzierżyńska-Białończyk, UMK Toruń) and internal

resources of the university. They resulted in publications: item 1 and 8 in Part B of point II of Annex 4.

Awards and distinctions received for scientific activity:

- Scholarship of the Minister of Science and Higher Education for PhD students for outstanding scientific achievements (2015/2016)
- Individual awards of the Rector of the Nicolaus Copernicus University for outstanding achievements in the field of scientific research (2018, 2021)
- NCU Rector's scholarship for highly scored publications (2018, 2019, twice in 2021 2020, twice in 2021, 2022)
- Distinction of the doctoral dissertation by the Council of the Faculty of Biology and Environmental Protection of the Nicolaus Copernicus University (2017)

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(Applicant’s signature)