Summary of Professional Accomplishments

1. Name: **Anna Iglikowska**

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 PhD dissertation.

- 1999-2004 – study in the Department of Biology, Geography and Oceanology of the University of Gdańsk, Department of Genetics
- 30 June 2004 – acquiring the M.Sc. degree, title of thesis: "Ostracods of Inarijärvi and surroundings (Finnish Lapland)", supervisor: prof. Tadeusz Sywula
- 2002-2007 – study on Stanisław Moniuszko Academy of Music in Gdańsk, Faculty of Instrumental Studies
- 16 June 2007 – acquiring the Master of Arts degree, title of thesis: „The problem of concentration of attention in pianists", supervisor: dr. Paweł Rydel
- 2004-2009 – Ph. D studies on the Faculty of Biology of Gdańsk University, Department of Genetics
- 5 November 2010 – acquiring of the Ph.D. degree, title of thesis: "The influence of abiotic environmental factors on occurrence and diversity of ostracods in selected types of freshwater habitats in Poland and Lapland", supervisor: prof. Tadeusz Namiotko

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

- 10 November 2010-30 June 2017 – at the Institute of Oceanology of the Polish Academy of Sciences in Sopot, Marine Ecology Department

2010-2012 as an 'oceanographer'

2012-2017 as a research scientist

- 1 October 2019-current workplace – University of Gdańsk, Faculty of Biology, Department of Evolutionary Genetics and Biosystematics as a lecturer and research scientist

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

Scientific achievement title:

Factors influencing bioaccumulation of chemical elements in the skeletons of marine invertebrates in the Arctic

1) Iglikowska, A., Bełdowski, J., Chełchowski, M., Chierici, M., Kędra, M., Przytarska, J., Sowa, A., Kukliński, P. 2017. Chemical composition of two mineralogically contrasting Arctic bivalves' shells and their relationships to environmental variables. Marine Pollution Bulletin 114 (2): 903-916.

My contribution to this publication included:
- conceptualisation
- sampling in the field during the R/V *Oceania* AREX cruise in 2014
- laboratory work – cleaning of specimens and sample mineralisation before chemical analysis
- data processing and interpretation – statistics, numerical analyses and data visualisation
- review and selection of literature
- the principal author of the manuscript text

2) Iglikowska, A., Najorka, J., Voronkov, A., Chełchowski, M., Kukliński, P. 2017. Variability in magnesium content in Arctic echinoderm skeletons. Marine Environmental Research 129: 207-218.

My contribution to this publication included:
- conceptualisation
- sampling in the field during the Norwegian R/V *Johan Hjort* cruise in 2015
- laboratory work – preparation of skeletons and their homogenisation
- conducting XRD analyses
- data processing and interpretation – statistical analysis and data visualisation
- review and selection of literature
- the principal author of the manuscript text

3) Iglikowska, A., Borszcz, T., Drewnik, A., Grabowska, M., Humphreys-Williams, E., Kędra, M., Krzemińska, M., Piwoni-Piórewicz, A., Kukliński, P. 2018. Mg and Sr in Arctic echinoderm calcite: Nature or nurture?. Journal of Marine Systems 180: 279-288.

My contribution to this publication included:
- conceptualisation
- laboratory work – sample mineralisation before chemical analysis
- conducting ICP AES analyses
- data processing and interpretation – statistical analysis and data visualisation
- review and selection of literature
- the principal author of the manuscript text

4) Iglikowska, A., Ronowicz, M., Humphreys-Williams, E., Kukliński, P. 2018. Trace element accumulation in the shell of the Arctic cirriped *Balanus balanus*. Hydrobiologia 818 (1): 43-56.

My contribution to this publication included:
- conceptualisation
- sampling in the field during the R/V *Oceania* AREX cruise in 2014
- laboratory work – sample mineralisation before chemical analysis
- data processing and interpretation – statistics, numerical analyses and data visualisation
- review and selection of literature
- the principal author of the manuscript text

5) Iglikowska, A., Humphreys-Williams, E., Przytarska, J., Chełchowski, M., Kukliński, P. Minor and trace elements in skeletons of Arctic echinoderms. 2020. Marine Pollution Bulletin 158, 111377.

My contribution to this publication included:
- conceptualisation
- sampling in the field during the Norwegian R/V *Johan Hjort* cruise in 2015
- laboratory work – preparation of skeletons and their homogenisation as well as sample mineralisation before chemical analysis
- conducting ICP AES analyses

- data processing and interpretation – statistics, numerical analyses and data visualisation
- review and selection of literature
- the principal author of the manuscript text

6) Iglikowska A., Krzemińska M., Renaud P., Berge J., Hop H., Kuklinski P. 2020. Summer and winter Mg levels in skeleton of Arctic bryozoans. Marine Environmental Research: 105166.

My contribution to this publication included:
- conceptualisation
- conducting XRD analyses
- data processing and interpretation – statistical analysis and data visualisation
- review and selection of literature
- the principal author of the manuscript text

Number of publication	Journal	Year	IF/IF 2022*	Number of points**	Quartile***
1	Marine Pollution Bulletin	2017	3.241/5.553	40/100	1
2	Marine Environmental Research	2017	3.159/3.13	35/100	1
3	Journal of Marine Systems	2018	2.539/2.542	40/100	2
4	Hydrobiologia	2018	2.325/2.822	30/100	2
5	Marine Pollution Bulletin	2020	5.553/5.553	100	1
6	Marine Environmental Research	2020	3.13/3.13	100	1

*IF in the year of publication/IF 2-years for 2021-2022

** according to the annexe to the communication of the Minister of Education and Science in the year of publication/in December 2021.

***according to Web of Science Core Collection

Introduction

The habilitation dissertation consists of six research papers published in international journals. The main topic of the cycle is the bioaccumulation of chemical elements (macroelements, microelements and trace elements) in skeletons of several taxonomic groups of benthic invertebrates inhabiting the Arctic seas.

Progressing climate changes particularly affect polar ecosystems (e.g., Andersson et al. 2008). Recent studies predict that air temperature is rising twice as fast in the Arctic as the average warming rate elsewhere in the world (IPCC 2021). Raising temperatures increase melting of glaciers and disappearance of sea ice, resulting in the seawater freshening and exposure of surface waters to more intense absorption of atmospheric carbon dioxide (CO_2). In seawater, dissolved CO_2 occurs mainly in the form of a bicarbonate ion (HCO^{3-}) and carbonic acid (H_2CO_3), which, in higher concentrations, reduce the pH of seawater. This phenomenon is known as an ocean acidification (e.g., Feely et al. 2004). Declining seawater pH can affect the physiological processes of marine organisms such as metabolic activity, growth, development, reproduction and many others (Michaelidis et al. 2005, Miles et al. 2007). The lower seawater pH can also limit the availability of carbonates to marine invertebrates, which is crucial for species producing shells and skeletons made of calcium carbonate ($CaCO_3$) (Fabry et al. 2008).

The calcareous skeleton serves as a shield for an organism, protecting it against predators and the influence of unfavourable abiotic conditions of the ambient environment. In addition, the skeleton protects soft tissues against mechanical damage and supports muscles and tendons. For many marine invertebrates, the shell or skeleton is also a calcium reservoir, which, in case of a calcium deficit, can be used in metabolic processes (Weiner and Addadi 1997, Alyakrinskaya 2005). Invertebrates use two main polymorphs of calcium carbonate to build the skeleton: aragonite and calcite. Both minerals have identical chemical composition ($CaCO_3$), but differ in their crystal lattice structure: aragonite has an orthorhombic crystal system, whereas a trigonal crystal system characterises calcite. Marine invertebrates can produce entirely aragonitic or purely calcitic skeletons, but some taxonomic groups are able to precipitate both minerals together in a one shell (bimineralic skeletons) (Lowenstam and Weiner 1989). Numerous reports confirmed that the production of a particular skeletal mineral is genetically determined and common to closely related phylogenetically species (e.g., Taylor et al. 1969). Aragonite and calcite differ in their chemical stability in seawater, as well as in their mechanical properties. Generally, aragonite has a denser structure; therefore it is considered a harder and mechanically stronger mineral, and, consequently, a more robust skeletal material (Jackson et al. 1988). However, metastable aragonite is more susceptible to dissolution in cold Arctic waters. Thus organism needs to spend more energy to maintain a dense, fully calcified skeleton (e.g., Andersson et al. 2008).

The calcareous skeleton is built by an organism through calcification (biomineralization). In calcification process, the skeleton is precipitated using elements available in seawater, and besides calcium and carbonate ions, the skeleton consists of trace elements. Some trace elements (e.g., Mg, Sr) enhance mechanical parameters of the skeleton (Kunitake et al. 2012), while others (e.g., Zn, Cd) distort the crystal lattice of the skeleton, which often adversely affects the chemical stability of carbonate lattice (Reeder 1983). Many factors influence the uptake and incorporation of chemical elements into the crystal structure of the skeleton by marine invertebrates. Biological factors include a metabolic activity of an organism, growth rate, diet, synthesised mineral (aragonite or calcite), and genetic regulation (e.g., Morrison and Brand 1986). The chemical composition of the skeleton can also be shaped by environmental factors such as seawater temperature, salinity, pH and calcium carbonate saturation state (expressed as Ω), metal concentration in the surrounding water/bottom sediment, the bioavailability of these metals and many others (e.g., Morrison and Brand 1986).

This habilitation cycle focuses on examining the factors that may drive the bioaccumulation of elements in the skeletons of different species of benthic invertebrates in the Arctic. The study's main goal was to assess to what extent calcification in marine invertebrates is a passive process, shaped only/mainly by abiotic conditions, and to what extent it is a biologically controlled process. If the skeleton deposition is regulated mainly by the ambient environmental conditions, then over the next 100 years, expected changes in the carbonate chemistry of Arctic seawaters may set up physico-chemical barriers effectively hindering the formation and maintenance of the calcareous skeleton (e.g., Fabry et al. 2008). On the other hand, when the calcification process is mainly biologically regulated, it gives a chance to develop adaptations to the precipitation of the skeleton, even under unfavorable conditions. However, the efficient calcification process under low carbonate availability is expected to increase energetic costs, which may adversely affect other physiological processes such as energy storage and reproduction, reducing overall organism fitness.

Calcifying invertebrates are numerous, diverse and ecologically important components of benthic communities in the Arctic. Calcifying organisms represent various taxonomic groups and trophic levels. They include planktonic invertebrates (Pteropod gastropods), sessile benthic organisms (bryozoans, barnacles, sea lilies) and active moving invertebrates (crustaceans, Serpulidae polychaetes, chitons, bivalves, gastropods, brachiopods, echinoderms and others). Possession of a robust skeleton determines the survival of calcifying organisms. Because the chemical composition of the skeleton is related to its chemical stability (e.g., Reeder 1983), knowledge of the processes shaping the bioaccumulation of elements enables us to assess the susceptibility/resistance of organisms to the changing chemistry of Arctic seawaters and to reveal taxonomic groups particularly threatened by the consequences of climate changes in the Arctic.

All presented publications share the same study area – the European Arctic, furthermore, implemented analytical methods are an additional bonding element. In all papers, the mineral composition of the skeleton was determined using the XRD technique (X-ray diffraction). The XRD enabled us to distinguish the $CaCO_3$ polymorph, estimate the percentage of minerals in bimineralic shells and measure magnesite ($MgCO_3$) content in the skeleton of organisms precipitating calcite with varying magnesium content. To determine the chemical composition of the skeletons, the new, high-tech and recently popular ICP (ICP MS, inductively coupled plasma mass spectrometry and ICP AES, inductively coupled plasma atomic emission spectroscopy) technique was used, based on the ionisation of a sample in inductively coupled plasma. Implementing the same analytical methods (and often the same machines) enables a reliable comparison of obtained results and also emphasises the linkage of articles within the cycle.

Publication 1: Chemical composition of two mineralogically contrasting Arctic bivalves' shells and their relationships to environmental variables

The first publication is focused on the influence of shell mineral composition (i.e. mineralogy) on the process of trace elements incorporation in the carbonate crystal lattice. Two common Arctic bivalve species have been chosen as model organisms: the scallop *Chlamys islandica* (O.F. Müller, 1776) and the cockle *Ciliatocardium ciliatum* (Fabricius, 1780). These bivalves differ in shell mineralogy: the scallop possesses mostly calcitic shell, whereas the cockle has purely aragonitic shell. Furthermore, these species occupy different habitats: scallops inhabit the hard bottom surface, while cockles live buried in the soft bottom sediment. Based on the obtained results, aragonite was found to be more susceptible to binding foreign (other than Ca) metal ions, which is a likely consequence of its crystal lattice structure. However, aragonitic cockles live in the bottom sediment and thus are exposed to different abiotic conditions than scallops. Variable and complex chemical conditions characterise bottom sediment. The process of sediment mineralisation produces CO_2 which decreases pH by up to 1 unit concerning the values observed in seawater above the sediment (Fenchel and Riedl 1970). Earlier reports indicated that at lower pH, most metals are released from the sediment into solution (Millero et al. 2009), thus becoming more available to living organisms (Pascal et al.

2010, Lacoue-Labarthe et al. 2009, 2011). The obtained data suggest that cockles tend to incorporate more metallic ‘impurities’ into the aragonite crystal lattice because they live in a habitat characterised by a lower pH, where metal ions are more readily available. Consequently, higher concentrations of foreign ions can increase the distortion of the aragonite structure, resulting in lower lattice stability and greater susceptibility to dissolution. Because the vast majority of bivalve molluscs living in the bottom sediment have entirely aragonitic shells, these species had to develop a strategy in their evolutionary history to protect the skeleton against chemical degradation of the crystal lattice. Previous studies reported that all species living in the sediment have a relatively thick (Harper 1997: even 317 μm) layer of organic periostracum, which protects the shell surface from dissolution. For comparison, the periostracum produced by species inhabiting the surface of the hard bottom forms a much thinner layer (Harper 1997: <1 μm). In this study, low concentrations of metals were recorded in the shells of scallops living on the hard bottom surface. Calcitic shells appeared less susceptible to binding metal ions than aragonitic shells. Calcite deposition is likely carried out under strict biological control of an organism (Carter et al. 1998), and the uptake of ions from the surrounding seawater is, therefore, more selective. Thus, the calcite crystal lattice is less contaminated with foreign metals and therefore less prone to dissolution.

Publication 2: Variability in magnesium content in Arctic echinoderm skeletons

The second paper deals with the accumulation of magnesium in a skeleton of different species representing all five classes of echinoderms: starfish Asteroidea, sea urchins Echinoidea, brittle stars Ophiuroidea, sea cucumbers Holothuroidea and sea lilies Crinoidea. Magnesium is a special element in the calcite structure since it increases the mechanical properties of skeleton (Kunitake et al. 2012, Long et al. 2014). The skeleton composed of high-Mg calcite was reported to be harder, more elastic and flexible when compared to low-Mg calcite (Ma et al. 2008). Unfortunately, in the cold waters of the Arctic, calcite with a high magnesium content is metastable and thus more prone to dissolution in seawater (Raz et al. 2000, Dubois 2014), hence the deposition of such skeleton is more energetically costly for calcifying organisms. Because echinoderms are known to maintain high levels of magnesium in their skeletons (Schroeder et al. 1969: max. 43.5 mol% $MgCO_3$), we expect that they are particularly vulnerable to changes in seawater chemistry in the Arctic. Our results indicate that the concentration of Mg in echinoderm skeleton is characteristic of the echinoderm class and specific to the species. Generally, the highest Mg content was observed in starfish, slightly lower in brittle stars, sea lilies and sea cucumbers, and the lowest in sea urchins. We observed that species with skeletons isolated from seawater, i.e. produced inside the organism, can maintain a hard and elastic skeleton with a high-Mg content. In starfish, the skeleton is covered with a thick layer of skin and connective tissue. Therefore, the skeletal high-Mg calcite is not in direct contact with seawater. In sea urchins, skeletal elements are more exposed to the influence of seawater. Sea urchin spines are covered only with a thin epidermal layer. Therefore, calcite with a much lower magnesium content makes them less susceptible to dissolution at low seawater temperature and low carbonate availability. These results strongly suggest that the particular Mg content in the echinoderm skeleton is a kind of compromise: producing the hardest possible skeleton while keeping the production costs as low as possible. This finding reveals the role of natural selection in shaping the observed calcification strategy in Arctic echinoderms and thus supports the thesis of biological (most likely genetic) regulation of Mg concentration in the skeleton.

Publication 3: Mg and Sr in Arctic echinoderm calcite: Nature or nurture?

The results of the next publication focused on answering whether the distribution of skeletal elements (Mg and Sr) is homogeneous within the organism or whether different concentrations of both elements characterise specific body parts. The study examined 10 species of Arctic echinoderms representing three classes: starfish Asteroidea, brittle stars Ophiuroidea and sea urchins Echinoidea. We found significant differences in the Mg and Sr contents among specific body parts in sea urchins but without clear trends in starfish and brittle stars.

The lowest Mg and Sr concentrations were observed in sea urchin spines, while the highest levels of both elements characterised the mouth parts (Aristotle's lanterns). Sea urchins use Aristotle's lantern to acquire food (scraping flora and fauna from the bottom surface and stones), bury in sediment, dig holes in the hard bottom, and to some extent for locomotion (Candia Carnevalli et al. 1993). Sea urchin's mouth parts likely experience greater mechanical loads than other body parts. The higher concentration of Mg in Aristotle's lantern contributes to increased hardness and strength of skeletal elements. The Aristotle lantern is located inside the body; thus, the high-Mg calcite is less exposed to the corrosive influence of seawater. On the other hand, sea urchin spines are highly exposed to the direct impact of seawater. Hence the low Mg content can make them less susceptible to dissolution, although the mechanical properties of such spines may be weaker. The heterogeneous concentrations of Mg and Sr in different parts of the sea urchin skeleton suggest that the organism can regulate the distribution of chemical elements within the specific skeletal parts.

Publication 4: Trace element accumulation in the shell of the Arctic cirriped *Balanus balanus*

The fourth article focused on a single sessile species: the barnacle *Balanus balanus* (Linnaeus, 1758), representing cirripeds (Cirripedia, Crustacea). The study's main aim was to test two hypotheses: 1) the chemical composition of the *B. balanus* shell is mostly controlled biologically, and environmental factors have only minor influences, and 2) the chemical composition of *B. balanus* shells does not vary with size. Based on our study, significant differences in the chemical composition among different skeletal parts were revealed. Since all body parts within the skeleton are deposited under the same environmental conditions (sedentary adult organism), a heterogeneous accumulation pattern may indicate biological control on the distribution of the elements in the skeleton. Our results revealed that *operculum* was the most distinctive skeletal plate, with higher Mg, S and Sr concentrations. According to earlier studies the presence of Mg and Sr in carbonate structure can enhance the mechanical properties of the skeleton. At the same time sulphur is known as an element usually included within organic matter associated with the skeleton (Cusack et al. 2008: sulphur-containing amino acids, Gorzelak et al. 2013: sulphated polysaccharides). *Balanus* opens the *operculum* when it needs to use feathery legs for food gathering. In contrast, the *operculum* closes when the organism wants to avoid adverse environmental factors (e.g., predators or lack of water at low tide). The obtained results imply that the selective uptake of *operculum*-building elements may be related to the required mechanical properties of this skeletal part. Therefore it is likely that a specific chemical composition of the *operculum* improves the adaptive properties of the organism. For most studied elements, no relationship was found between metal accumulation patterns and body size, even though body size is related to age and, thus, to other age-related characteristics (e.g. metabolic activity). Only for barium (Ba), we found a positive correlation between element concentration and body size since the lowest Ba concentrations characterised the youngest individuals, and larger (older) specimens showed higher Ba levels. A possible explanation for this relationship is the lack of a physiological mechanism for Ba elimination from the crystal lattice of the skeleton. The results of the conducted study confirmed both examined hypotheses.

Publication 5: Minor and trace elements in skeletons of Arctic echinoderms

The fifth publication of the series is again about echinoderms, but this study focuses on the bioaccumulation of 12 micro- and trace elements (Al, Ba, Ca, Fe, K, Mg, Mn, Na, P, S, Sr, Zn) in five species (two starfish species – *Ctenodiscus crispatus* (Bruzelius, 1805) and *Pontaster tenuispinus* (Düben & Koren, 1846), two brittle star species – *Ophiopholis aculeata* (Linnaeus, 1767) and *Ophiura sarsii* Lütken, 1855, and one sea lily species – *Heliometra glacialis* (Owen, 1833)) inhabiting the Barents Sea. In the study area, the hydrological conditions are shaped by two different water masses: warmer and more saline Atlantic waters and cooler and less saline Arctic water masses. In the study, we found that Arctic echinoderms exhibit a unique species-specific elemental composition, which may suggest biological control over the selective uptake of elements into a skeleton. Starfish showed high concentrations of all examined elements (especially K, Na, P, and S), while the lowest element levels were found in brittle stars. The higher contents of Zn and S were recorded in sea lilies, although the concentration of other metals was significantly lower in this group. We also compared the bioaccumulation of elements in the skeleton among specimens collected from different stations. Station-specific skeletal contents of Al, Ba, Fe, Mg and Mn were observed, which indicates that the accumulation of metals may also be shaped by the availability of these elements in seawater or bottom sediment. Interestingly, the concentration of elements in echinoderm skeletons followed the order: Na > S > K > Sr > trace metals, which is similar to the pattern observed in seawater (e.g., Sverdrup et al. 1970). This finding suggests that despite the dominance of biological control over the incorporation of elements, the chemical composition of the skeleton is also influenced to some extent by environmental factors. Seawater is the main source of the elements and ions for calcification process. Echinoderms may maintain a similar level of elements in the skeleton to reduce the energy costs associated with the selective uptake of ions. However, station-related pattern in skeletal chemistry have not correlated with the influence of warm Atlantic and cold Arctic water masses. Unfortunately, based on the field studies, it was not possible to identify specific abiotic factors shaping the uptake of elements into echinoderm skeleton. The skeleton's chemical composition results from lifelong accumulation (few or several years in echinoderms). It seems logistically impossible to monitor the environmental exposure of actively moving organism over such a long period.

Publication 6: Summer and winter Mg levels in skeleton of Arctic bryozoans

The last article of the series deals with sessile invertebrates – Arctic bryozoans. Ambient abiotic conditions are important for sedentary organisms since these animals cannot escape unfavorable environmental changes.

Magnesium is an important component of biogenic carbonates because it can influence its mechanical properties and chemical stability. In seawater, the Mg concentration is relatively high (Stanley and Hardy 1998: Mg/Ca = 5.2), which determines the high availability of this element for organisms. In abiogenic carbonates (precipitated without the involvement of living organisms), the deposition of a specific $CaCO_3$ polymorph is driven by the rate of crystal growth (Given and Wilkinson 1985). In warmer waters, a faster crystal growth rate stimulates the formation of aragonite or calcite with a high-Mg content. In comparison, a lower crystal growth rate in colder waters leads to calcite deposition with a low-Mg content (Given and Wilkinson 1985). This relationship suggests that in polar waters, the physicochemical properties of seawater favour the precipitation of calcite with a low-Mg content. Nevertheless, in biogenic calcite (produced by living organisms), a wide range of Mg content can be observed even in fauna inhabiting polar seas, which is attributed to the biological regulation of the calcification process (Long et al. 2014).

In Arctic seas, biochemical conditions are shaped, among others, by the alternation of polar day and polar night. In summer, CO_2 is acquired by phytoplankton for photosynthesis. The CO_2 uptake increases the pH of the seawater and thus increases the seawater carbonate saturation state (Ω). This process is observed in the euphotic zone. Therefore, a depth-related gradient in the carbonate saturation state is expected. On the other hand, in winter, during the polar night, when primary production is significantly reduced, respiration processes increase the CO_2 content in the water. The higher CO_2 concentration decreases pH, which consequently reduces Ω of seawater. In this study, we examined whether changes in the carbonate seawater chemistry resulting from the activity of autotrophic organisms under the influence of sunlight could affect the accumulation of Mg in the calcitic skeletons of Arctic bryozoans. Our results showed no differences between the summer and winter content of skeletal $MgCO_3$ in the five species of examined bryozoans, even though the differences in the seawater Ω between the two seasons were statistically significant. Additionally, no depth-related differences in skeletal $MgCO_3$ content were detected. Interestingly, all examined species showed high (> 8 mol%) content of $MgCO_3$ in skeletal calcite. The deposition of high-Mg calcite in the cold waters of the Arctic seas requires the support of additional mechanisms enhancing the mineralisation process, e.g. the involvement of ion pumps used by living organisms in the calcification process (e.g., Zoccola et al. 2015). Furthermore, observed species-specific levels of $MgCO_3$ confirm that physiological processes drive the biomineralisation process in Arctic bryozoans. The lack of observed differences in Mg accumulation in bryozoans in the depth gradient and those synthesized during polar day/night may result from generally favourable conditions regarding the calcite saturation state of seawater. During the study period, Arctic seawater – despite the observed climate changes – was still sufficiently saturated with carbonates (especially calcite), even in the winter season, which is typically characterised by a higher content of CO_2. Nevertheless, it should be emphasised that both the analysis of Ω in seawater and the analysis of $MgCO_3$ in bryozoan skeletons were carried out at relatively shallow depths (max. 150 m). The results at greater depths could likely show less optimistic values. Moreover, in the Arctic, CO_2 concentration in seawater is increasing due to the progressing reduction in ice cover. Expected changes in the CO_2 concentration, and hence the seawater Ω, include – among others – shallowing of the zone where biogenic calcification is supported by favourable physicochemical conditions ($\Omega > 1$). In deeper waters, a high concentration of CO_2 is observed, and water is less saturated with carbonates ($\Omega < 1$), which leads to the dissolution of carbonates. Therefore, the synthesis of the skeleton under such conditions is extremely energy-consuming. Thus, the habitat for calcifying organisms is gradually shrinking due to the physicochemical limitations of the calcification process. This problem will most severely affect organisms producing high-Mg calcite, such as bryozoans examined in this study.

Summary and conclusions

The series of publications presented above employed new and hi-tech methods of chemical analysis to explain ecological problems originally and innovatively. The integration of advanced analytical methods and classical approaches used in environmental ecology provided insight into the poorly known level of diversity (i.e. the chemical variability of the skeleton). Also, it enabled tracking of the responses of calcifying organisms to changing chemical conditions in the Arctic seas. The most important achievement of my research was: 1. Proving that benthic invertebrates in the Arctic are characterised by a unique chemical composition of the skeleton for the species; 2. Revealing the dominant influence of biological factors on the process of metal incorporation in the skeletons of Arctic invertebrates, and finally 3. Identification of taxonomic groups which are expected to show first the negative consequences of climate changes in the Arctic.

For most taxa, studies on metal bioaccumulation have focused mainly on soft tissues, as this approach enables tracking how metals are introduced into food webs. Data on skeletal accumulation patterns have been fragmentary so far. Previous reports on the concentration of metals in the skeleton of invertebrates were mainly carried out in the seas of the temperate zone, which are under considerable anthropogenic pressure and hence often heavily contaminated with metals. Therefore, the observed high concentrations of certain elements in the skeleton were considered as a result of exposure to high concentrations of metals in the environment. My research was conducted in high Arctic conditions, where anthropogenic metal contamination is negligible, yet I observed relatively high concentrations of certain elements in invertebrate skeletons. This observation proves that the chemical composition of the skeleton is not a passive reflection of the chemical composition of the surrounding environment. Most likely, the skeleton's relatively constant and species-specific chemical and mineral composition is genetically determined and shaped by natural selection. The obtained results strongly suggest that the organism regulates the uptake and incorporation of particular elements in the crystal lattice of the skeleton because it increases organism adaptation.

Because climate change in the Arctic is progressing at an extremely fast pace, it seems crucial to determine to what extent the calcification process in invertebrates is a passive reflection of environmental conditions and to what extent animals can regulate the deposition of the carbonate skeleton. The presented publications provided evidence that many groups of invertebrates have developed a variety of adaptations which enable them to carry out effective biomineralisation in conditions of lower pH, reduced availability of carbonates and increased availability of metals in the surrounding marine environment. They include the presence of a sufficiently thick layer of periostracum adapted to a specific ecological niche (in bivalves), isolation of the internal skeleton under a thick layer of skin and connective tissue (in starfish), skeletal chemical composition adapted to conditions of high exposure to the corrosive ambient seawater (in sea urchins), the concentration of elements supporting mechanical parameters of the skeleton only in those body parts which are crucial for survival (in barnacles and sea urchins) and, above all, selective uptake of elements from the environment which leads to species-specific chemical composition of a skeleton (in most calcifying species) and others.

Unfortunately, the development of new adaptations is a long-term process. The observed climate changes and associated alterations in the chemistry of seawater in the Arctic are progressing faster and faster. Declining pH, carbonate undersaturation observed at shallower depths, and the increasing availability of metals in the environment may significantly increase the energetic costs of the calcification process, especially in taxa depositing aragonite or calcite with a high-Mg content. Therefore, based on the obtained results, bryozoans and echinoderms which produce calcite with a high-Mg level, seem to be the first groups that will suffer from the consequences of the expected changes in the seawater chemistry. Increasing energy expenditure related to skeleton deposition will limit other physiological processes (e.g. reproduction) or lead to the precipitation of poorly calcified, weaker skeletons. Invertebrates with weaker skeletons will be more susceptible to predation pressure and interspecies competition. As a result, some species and even groups of species may be displaced by other, better-adapted taxa. The situation is even worse since the expansion of boreal species is expected due to the progressive warming of the climate. In the Arctic seas, calcifying invertebrates are an important component of the ecosystem, contributing to the carbon cycle as well as to cycles of other elements (e.g. nitrogen, calcium, sulphur, phosphorus and trace elements). The elimination of certain species or the dramatic reduction of their abundance may lead to the destabilization of food webs and rapid alterations of the trophic relationships in the Arctic ecosystem. Thus, the highly effective mechanisms of biomineralisation that have enabled calcifying organisms to thrive in polar ecosystems for millions of years will soon be severely tested, facing the consequences of the climate changes already taking place in the Arctic.

References

Alyakrinskaya, I.O. 2005. Functional significance and weight properties of the shell in some mollusks. Biology Bulletin 32(4): 397-418.

Andersson, A.J., Mackenzie, F.T., Bates, N.R. 2008. Life on the margin: implications of ocean acidification on Mg-calcite, high latitude and cold-water marine calcifiers. Marine Ecology Progress Series 373: 265-273.

Carnevali, C., Wilkie, I.C., Lucca, E., Andrietti, F., Melone, G. 1993. The Aristotle's lantern of the sea-urchin *Stylocidaris affinis* (Echinoida, Cidaridae): functional morphology of the musculo-skeletal system. Zoomorphology 113(3): 173-189.

Carter, J.G., Barrera, E., Tevesz M.J. 1998. Thermal potentiation and mineralogical evolution in the Bivalvia (Mollusca). Journal of Paleontology 72(6): 991-1010.

Cusack, M., Dauphin, Y., Cuif, J.P., Salomé, M., Freer, A., Yin, H. 2008. Micro-XANES mapping of sulphur and its association with magnesium and phosphorus in the shell of the brachiopod, *Terebratulina retusa*. Chemical Geology 253(3-4): 172-179.

Dubois, P. 2014. The skeleton of postmetamorphic echinoderms in a changing world. The Biological Bulletin 226(3): 223-236.

Fabry, V.J., Seibel, B.A., Feely, R.A., Orr, J.C. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65: 414-432.

Feely, R.A., Sabine, C.L., Lee, K., Berelson, W., Kleypas, J., Fabry, V.J., Millero, F.J. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. Science 305(5682): 362-366.

Fenchel, T.M., Riedl, R.J. 1970. A new biotic community underneath oxidized layer of marine sand bottoms. Marine Biology 7: 255-268.

Given, R.K., Wilkinson, B.H. 1985. Kinetic control of morphology, composition, and mineralogy of abiotic sedimentary carbonates. Journal of Sedimentary Research 55: 109-119.

Gorzelak, P., Stolarski, J., Mazur, M., Meibom, A. 2013. Micro- to nanostructure and geochemistry of extant crinoidal echinoderm skeletons. Geobiology 11: 29-43.

Harper, E.M. 1997. The molluscan periostracum: an important constraint in bivalve evolution. Palaeontology 40: 71-97.

IPCC 2021. Summary for Policymakers, in: Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M.,Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., Zhou, B. (Eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Jackson, A.P., Vincent, J.F., Turner, R.M. 1988. The mechanical design of nacre. Proceedings of the Royal Society of London. Series B. Biological Sciences 234(1277): 415-440.

Kunitake, M.E., Baker, S.P., Estroff, L.A. 2012. The effect of magnesium substitution on the hardness of synthetic and biogenic calcite. MRS Communications 2: 113-116.

Lacoue-Labarthe, T., Martin, S., Oberhänsli, F., Teyssié, J.L., Markich, S., Jeffree, R., Bustamante, P. 2009. Effects of increased pCO_2 and temperature on trace element (Ag, Cd and Zn) bioaccumulation in the eggs of the common cuttlefish, *Sepia officinalis*. Biogeosciences 6(11): 2561-2573.

Lacoue-Labarthe, T., Reveillac, E., Oberhänsli, F., Teyssié, J.L., Jeffree, R., Gattuso, J.P. 2011. Effects of ocean acidification on trace element accumulation in the early-life stages of squid *Loligo vulgaris*. Aquatic Toxicology 105(1): 166-176.

Long, X., Ma, Y., Qi, L. 2014. Biogenic and synthetic high magnesium calcite – A review. Journal of Structural Biology 185: 1-14.

Lowenstam, H.A., Weiner, S. 1989. On biomineralization. Oxford University Press, New York, 324 pp.

Ma, Y., Cohen, S.R., Addadi, L., Weiner, S. 2008. Sea Urchin Tooth Design: An "All-Calcite" Polycrystalline Reinforced Fiber Composite for Grinding Rocks. Advanced Materials 20: 1555-1559.

Michaelidis, B., Ouzounis, C., Paleras, A., Pörtner, H.O. 2005. Effects of long-term moderate hypercapnia on acid-base balance and growth rate in marine mussels *Mytilus galloprovincialis*. Marine Ecology Progress Series 293: 109-118.

Miles, H., Widdicombe, S., Spicer, J.I., Hall-Spencer, J. 2007. Effects of anthropogenic seawater acidification on acid–base balance in the sea urchin *Psammechinus miliaris*. Marine Pollution Bulletin 54(1): 89-96.

Millero, F.J., Woosley, R., Ditrolio, B., Waters, J. 2009. Effect of ocean acidification on the speciation of metals in seawater. Oceanography 22(4): 72-85.

Morrison, J.O., Brand, U. 1986. Paleoscene# 5. Geochemistry of recent marine invertebrates. Geoscience Canada 13(4): 237-254.

Pascal, P-Y., Fleeger, J.W., Galvez, F., Carman, K.R. 2010. The toxicological interaction between ocean acidity and metals in coastal meiobenthic copepods. Marine Pollution Bulletin 60: 2201-2208.

Raz, S., Weiner, S., Addadi, L. 2000. Formation of high-magnesian calcites via an amorphous precursor phase: possible biological implications. Advanced Materials 12: 38-42.

Reeder, R.J. 1983. Crystal chemistry of the rhombohedral carbonates. In: Reeder, R.J. (Ed.), Carbonates: Mineralogy and Chemistry. Reviews in Mineralogy and Geochemistry 11, 47 pp.

Schroeder, J.H., Dwornik, E.J., Papike, J.J. 1969. Primary protodolomite in echinoid skeleton. Geological Society of America Bulletin 80: 1613-1616.
Stanley, S.M., Hardie, L.A. 1998. Secular oscillations in the carbonate mineralogy of reef-building and sediment-producing organisms driven by tectonically forced shifts in seawater chemistry. Palaeogeography, Palaeoclimatology, Palaeoecology 144: 3-19.
Sverdrup, H.U., Johnson, M.W., Fleming, R.H. 1970. The oceans: their physics, chemistry and general biology. Prentice-Hall, Inc. Englewood Cliffs, N.J., 1088 pp.
Taylor, J.D., Kennedy, W.J., Hall, A. 1969. The shell structure and mineralogy of the Bivalvia. Introduction. Nuculacea-Trigonacea. Bulletin of the British Museum (Natural History) Zoology 3: 1-125.
Weiner, S., Addadi, L. 1997. Design strategies in mineralized biological materials. Journal of Materials Chemistry 7(5): 689-702.
Zoccola, D., Ganot, P., Bertucci, A., Caminiti-Segonds, N., Techer, N., Voolstra, C.R., Aranda, M., Tambutté, E., Allemand, D., Casey, J.R., Tambutté, S. 2015. Bicarbonate transporters in corals point towards a key step in the evolution of cnidarian calcification. Scientific Reports 5: 9983.

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

A complete list of my scientific achievements is presented in the appendix "List of scientific or artistic achievements which present a major contribution to the development of a specific discipline". Below I present an overview of my research activities.

In 1999, I started my studies at the University of Gdańsk (UG), Faculty of Biology, Geography and Oceanology (Faculty of Biology). Besides lectures and classes, I also developed my scientific interests by participating in activities of the hydrobiology group at the Department of Genetics, UG. After the second year of master's studies, I became interested in the hydrobiology and freshwater ecology of the Boreal-Arctic regions, which resulted in the organisation of two research expeditions to the Finnish Lapland (summer seasons 2002 and 2003). During the expeditions, I experienced the specifics of fieldwork and learned sampling methodology: collection of freshwater invertebrates, as well as measurements of the physicochemical parameters of an aquatic environment. The samples collected in Lapland became a basis for my master's thesis. Within my master's thesis, I studied Ostracoda species from Lake Inari and freshwater habitats (springs, peat bogs, temporary pools and others) located near the lake. Because freshwater Ostracoda in that area have never been explored so far, in my master's thesis I focused on faunistic examination. In 2003, as a third-year student, I presented for the first time the results of my research from Lapland at a conference (X Polish Workshops on Bentology in Ciążeń near Poznań), and one year later (2004) I was a co-organizer of another

Workshops on Bentology arranged in Jastrzębia Góra. In 2004, I defended my master's thesis entitled: "Ostracods of Inarijärvi and suroundings (Finnish Lapland)" under the supervision of prof. Tadeusz Sywula and dr. Tadeusz Namiotko. The results included in the master's thesis were published in the *Annales de Limnologie – International Journal of Limnology* (Iglikowska and Namiotko 2010).

After my master's studies, I continued my scientific activities as a student of doctoral study at the Institute of Biology of the University of Gdańsk. In 2004, the first supervisor of the thesis (prof. Tadeusz Sywula) died in a tragic accident. Therefore, I continued my doctoral studies under the supervision of prof. Lech Stempniewicz. The supporting supervisor of the doctoral project was dr. Tadeusz Namiotko, who became the final supervisor of my doctoral dissertation in 2008. In the summer season of 2004 and 2006, I was again a co-organizer of two research expeditions in northern Lapland (Norwegian, Swedish and Finnish Lapland) financed by two UG grants (BW-1130-5-0004-4 and BW-1411-5-0337-6). During the expeditions, I also took samples in southern Norway for the project "From Sex to Asex: a case study on transitions and coexistence of sexual and asexual reproduction" (MRTN-CT 2004-512492).

Compared to my master's thesis, in PhD, I expanded my research interests to include the analysis of the influence of abiotic factors in the aquatic environment on the species diversity of ostracods. In the study, I also compared the ostracod fauna from Lapland with species from Polish sites. In November 2010, I defended my doctoral dissertation entitled: "The influence of abiotic environmental factors on occurrence and diversity of ostracods in selected types of freshwater habitats in Poland and Lapland". In my doctoral thesis, I analysed the ostracod fauna of Poland and northern Lapland in three types of freshwater environments: lakes, peat bogs and temporary pools. The study's most important result was observing the diversified and specialized (stenobiontic) fauna of ostracods at Polish sites and uniform (eurybiontic) fauna at the sites in Lapland. The lack of differences in the species composition of the three types of freshwater habitats in Lapland I attributed to the periodic connection of water pools during spring thaws and the uniform physicochemical conditions of the aquatic environment. The doctoral dissertation results have been published in journals from the Journal Citation Reports (Iglikowska and Namiotko 2012a, b) and presented at five conferences.

After my doctoral defense, I started working in Institute of Oceanology of Polish Academy of Sciences in Sopot (IOPAS, Department of Marine Ecology, head of the department: prof. Jan Marcin Węsławski) employed in the project "ZSPDO: Integrated Ocean Data and Information Management System" (OPIG. 02.03.00-00-002/08). In the ZSPDO project, I worked in a research team led by dr. hab. Katarzyna Błachowiak-Samołyk and my task in the project was to digitise, organise and analyse oceanographic databases, which were the result of long-term research of IOPAS researchers. In January 2011, I presented my computer animation („The diversity of pelagic ostracods in the Central Eastern Atlantic Ocean") at the World Conference on Marine Biodiversity in Aberdeen (Scotland). During the project, I was also active in the research team dealing with the mathematical modelling of marine environments (Marine Dynamics Department, IOPAS). To expand my skills in mathematical modelling, I participated in a series of three training courses dedicated to hydrodynamic modelling (including ecological processes) using new and technologically advanced MIKE software from the Danish DHI group (www.dhigroup.com). Exploring the enormous potential of the MIKE program, together with a group of physicists from the Marine Dynamics Department (IOPAS), we prepared a model of salinity, temperature, currents, winds and sea ice of the Hornsund Fjord (Svalbard) for the project "GAME – growing of the Arctic marine ecosystem" financed by the National Science Center (DEC-2012/04/A/NZ8/00661). An additional activity of the group was preparing a hydrodynamic model of currents and winds in the Weymouth Bay (English Channel, UK) for Polish Olympians in the sailing competition, at the Olympic Games in London 2012. The prepared model supported Przemysław Miarczyński and Zofia Noceti-Klepacka in winning two bronze medals.

In 2012, I received funding for a foreign internship within the *Synthesys* program (www.synthesys.info). Under the supervision of prof. Geoffrey Boxshall I carried out the project entitled: „To undertake basic taxonomic research on the polyphyletic halocyprid ostracod genus *Paraconchoecia*" in the Natural History Museum (Darwin Centre) in London (UK). The results of studies conducted at NHM were two publications (Boxshall and Iglikowska 2012, Iglikowska and Boxshall 2013) and a description of a new for science deep-water species (*Thaumatoconcha angeli* Iglikowska & Boxshall, 2013) from the family Thaumatocyprididae. The type series of the species have been deposited at the Natural History Museum in London: holotype – female (NHMUK 2012.1520.), allotype – male (NHMUK 2012.1521.). The original description of the species (with a systematic revision) has been published in the journal *Zoologischer Anzeiger* (Iglikowska and Boxshall 2013). During the internship, I also completed a training course in scanning microscopy on the Zeiss Ultra Plus field emission SEM model. Later, I continued my cooperation with the Natural History Museum working in the Polish-Norwegian POLNOR project.

I decided to use my database preparation skills working for two well-known European programs: LifeWatch (www.lifewatch.eu) and EMODnet (European Marine Observation and Data Network – https://emodnet.ec.europa.eu/en). At the turn of 2012/2013, I prepared a database of Digenea (parasitic flatworms) for the popular and public World Register of Marine Species (WORMS) database (www.marinespecies.org/about.php), which is the result of the activity of LifeWatch program. In 2013, I prepared a global database of morphology, geographic distribution and biology of pelagic copepods (https://copepodes.obs-banyuls.fr/en/index.php) coordinated by the EMODnet organisation. As a result of both European programs activities, researchers from all over the world have free access to vast and comprehensive biological and oceanographic data resources, which serve as a basis for numerous research projects and other scientific and dissemination activities.

In 2012 and 2013, my scientific activity was honored with two individual awards of the director of the Institute of Oceanology of the Polish Academy of Sciences for research work and publications. Furthermore, in 2013, researchers from NIVA (Norwegian Institute for Water Research) in Oslo (Norway) showed interests in my research on the freshwater ostracod fauna. Due to the message exchange, researchers dr. Markus Lindholm and dr. Anders Hobaek arranged a scientific visit to the Faculty of Biology UG in May 2013. At the request of the guests, together with prof. Tadeusz Namiotko, we conducted consultations on species identification of freshwater Ostracoda. One year later, my review paper on the colonisation of the freshwater environment by the marine Ostracoda was published (Iglikowska 2014). After that I was asked to lecture on this subject at the University of Oslo (23 May 2014). In addition, during a research visit to Oslo, I was asked again to conduct consultations on identifying freshwater Ostracoda (with prof. Tadeusz Namiotko) in NIVA.

In 2014 I also started a new stage in my research activity: work in the Arctic on metal bioaccumulation in the skeletons of marine invertebrates. I joined a research group of prof. Piotr Kukliński working on the project entitled: "POLNOR – The Changing Ocean of the Polar North", financed by Polish-Norwegian grants and by the National Center for Research and Development (Pol-Nor/196260/81/2013). The POLNOR project was carried out in cooperation with research scientists from Norwegian institutes: NIVA (Norwegian Institute for Water Research) in Bergen and Akvaplan NIVA in Tromsø. The main research scope of the project was to assess to what extent the climate changes in the Arctic influence seawater acidification and whether the observed changes affect the calcification process in marine invertebrates. In the POLNOR project, I led a team working on metal bioaccumulation in the skeletons of benthic invertebrates. I completed a series of training courses at the Natural History Museum in London to prepare myself for a new role. Dr. Jens Najorka (a researcher in Core Research Laboratories at NHM) trained me in mineralogical analysis using the X-ray diffraction method (XRD), while dr. Emma Humphreys-Williams (a researcher in Imagine and Analysis Center at NHM) prepared me for work on trace elements analysis using ICP techniques (ICP AES, inductively coupled plasma – atomic emission spectroscopy and ICP MS, inductively coupled plasma – mass spectrometry). Supervised by both researchers, I conducted chemical and mineralogical analyses planned for the POLNOR project. Furthermore, the collaboration with dr. Jens Najorka and dr. Emma Humphreys-Williams has resulted in numerous publications (some are still in preparation or under review).

The implementation of tasks planned within the POLNOR project required sampling in the Arctic, therefore in July and August 2014, I participated in my first polar expedition to the Arctic: a research cruise on the R/V *Oceania* (IOPAS) along the fjords of West Spitsbergen (Svalbard). During the cruise with my team, we collected samples for the project; seawater samples for carbonate analysis were taken using a Niskin bottle, while calcifying benthic invertebrates were acquired using bottom dredge. One year later (August-September 2015) I participated in another research cruise on Norwegian vessel *Johan Hjort* (Institute of Marine Research, Bergen). The Norwegian cruise enabled me to learn new sampling techniques and collect echinoderm samples from the Barents Sea. In 2019 (June-August), I again participated in a research cruise of the *Oceania* (IOPAS) vessel, and sampling was carried out in the Norwegian Sea, Greenland Sea and the Arctic Ocean. During this expedition, I collected phyto- and zooplankton samples for genetic and faunistic examination, and seawater samples for genetic analysis of microbiome. All samples were taken for the project "HIDEA – the hidden diversity of plankton in the European Arctic", financed by the National Science Center (2017/27/B/NZ8/01056), and the project was carried out at the Institute of Oceanography UG. On all my cruises, besides being a member of the scientific team, I also participated in the preparations of the vessel and research equipment for the expeditions.

After the contract within the POLNOR project, I was not employed in any research institution for 2.5 years. I used this time to set up and run my own business. Because biology has always been my profession and my passion, the company's activity had to be related to biological sciences. As part of my business activity, I conducted courses and classes in biology for high school graduates planning to study at a medical university. During the break in my scientific employment, I also prepared, at the request of IOPAS, publications summarizing the results of the POLNOR project (Iglikowska et al. 2018a, b).

Encouraged by the teaching successes within my company's activity, in October 2019, I started work at the Faculty of Biology of the University of Gdańsk, where I could continue my educational activities. As a lecturer and research scientist of the Faculty of Biology UG, I continued my collaboration with the research team from IOPAS, and the result of this cooperation was articles published in the *Marine Pollution Bulletin* and *Marine Environmental Research* (Iglikowska et al. 2020a, b). In 2020, I also started a collaboration with the National Marine Fisheries Research Institute (MIR, Gdynia) in the field of studies on invertebrate fauna (plankton and benthos) of the southern Baltic seaports (Witalis et al. 2021, another publication under review). In 2020, I was asked by the Baltic Sea Cultural Center for a scientific consultation on a book dedicated to the youngest readers. The book "Baltek" by Anna Czerwińska-Rydel focuses on the ecological problems of the Baltic Sea and has been translated into all Baltic languages. The year 2020 also brought another scientific success: my articles published in 2020 contributed to the publication achievement of the research team of the Department of Genetics and Biosystematics of the University of Gdańsk, i.e. the 3rd-degree team award of the Rector of the University of Gdańsk for scientific activity.

In 2021, I received funding from the National Science Center for the project "Test of heavy metals bioaccumulation of aquatic crustaceans from the class Ostracoda" within the frame of the MINIATURA 5 call (DEC-2021/05/X/NZ8/00025). In this project, I could combine the knowledge about freshwater ostracods from the first stage of my scientific activity with the experience in the field of bioaccumulation of metals from a later period. Conducting breeding experiment, I examined the influence of Zn and Cu on the life history traits (survival, hatching success and dynamics, the duration of the development cycle, etc.) of *Heterocypris incongruens* from both laboratory populations (commercial Ostracodtoxkit f ® biotest) and natural populations. In the project, I also analysed the bioaccumulation of Zn and Cu in the tissues of ostracods bred in various concentrations of these elements.

In 2022, I presented the results of my research at two international conferences. In August, I was a co-author of oral presentation at the 19th International Bryozoology Meetings in Dublin (Ireland) concerning the mineralogical variability of bryozoans in a latitudinal gradient from the poles to the equator. Whereas in September, I presented my latest results on the bioaccumulation of metals in the shells of Arctic bivalves at the 55th European Marine Biology Symposium (EMBS) in Gdańsk. In 2022, I was also invited to participate in another polar expedition to the Antarctic region. During the cruise of the icebreaker *Noosfera* (National Antarctic Scientific Center of Ukraine), I was asked to carry out sampling in the Southern Ocean and Southern Shetland Islands. The cruise is planned for 2022 and 2023 (December-March). The new cruise brings new possibilities. I hope that the expedition to the Southern Ocean will be a source of new samples, new field experiences and scientific collaboration, and the beginning of a new phase of my research activity.

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

After my master's defense, as a student of doctoral studies, I started teaching students. These were mainly laboratories in *Genetics* for second-year Faculty of Biology students, as well as a laboratories for students preparing their master's theses at the Department of Genetics, Institute of Biology UG. Later, while working on the POLNOR project (IOPAS), I was the supervisor of scientific practices for Faculty of Oceanography students at the University of Gdańsk (Anna Sowa – January-December 2015, Edyta Głogowska – April-May 2015). In addition, in 2015, I was the supervisor of a one-year postgraduate internship in laboratory work related to the analysis of trace elements (Maciej Chełchowski, graduate of the University of Gdańsk).

When I started work at the University of Gdańsk, numerous new teaching activities appeared. To improve my teaching skills, I participated in the training "Developing teaching skills" arranged by the Center for Didactic Improvement and Tutoring of the University of Gdańsk. Since October 2019, I have supervised three bachelor's and four master's theses at the Faculty of Biology UG. I have also reviewed eight master's theses and two bachelor's theses of students of the Faculty of Biology UG, the Faculty of Chemistry UG and the Medical University of Gdańsk. Furthermore, since October 2021, I have been the supporting supervisor of the PhD thesis of Kamil Reginia, a student of the Tricity Doctoral School of the Polish Academy of Sciences. The title of the doctoral dissertation is: "Assessment of the impact of environmental conditions on the ecology and geochemistry of calcareous algae (Corallinales, Rhodophyta) of Western Spitsbergen (Arctic)", and the main supervisor of the doctoral dissertation is prof. Piotr Kukliński (IOPAS).

I conduct numerous lectures and classes with students at the Faculty of Biology of the University of Gdańsk. Since October 2019, I have conducted 13 subjects on various topics – including *Genetics* classes, a related to my scientific specialty lecture on the ecotoxicology (*Fundamentals of Ecotoxicology*), and classes preparing young people to write scientific texts (*Academic Writing*). I have also prepared two new subjects related to the ecological problems of the seas: *Basics of Marine Ecology* and *Baltic Sea Environment*, which are currently being conducted for the Faculty of Biology and OZP (Protection of Natural Resources) students.

Besides teaching, I was also involved in activities disseminating science. During the lockdown due to the COVID-19 epidemic, I prepared an online lecture for high school students entitled: "CO_2, the greenhouse effect and ocean acidification". Additionally, during the

"Biologists Night" event organised in January 2021 at the Faculty of Biology UG, I presented my amusing computer animation "What are bacteria doing in the sea?" for schoolchildren. In February 2021, I participated in an event popularising science, "Meeting with experts: will the Baltic Sea be with us?" arranged by the Baltic Sea Cultural Center for students and teachers of Secondary School No. 19 in Gdańsk. At the meeting, as one of the experts, I talked with young people about the current ecological problems of the Baltic Sea, and I answered numerous questions.

Topics of promoted BA theses:
- "The impact of the progressive climate warming on the biodiversity of marine invertebrates in the Arctic" – student of Faculty of Biology UG, Dominika Gruba, bachelor's thesis defense: 16^{th} July 2021
- "Impact of selected pharmaceuticals on aquatic ecosystems" – Julia Marczyńska, student of Faculty of Biology UG, bachelor's thesis defense: 16^{th} July 2021
- "Bioaccumulation of mercury in the skeletons of echinoderms from the Barents Sea" – student of Genetics and Experimental Biology UG, planned date of bachelor's thesis defense: July 2023

Topics of promoted master's theses:
- "Differentiation of the ostracod body size in freshwater assemblages against the background of basic climatic factors variability" – Jakub Krzyżewski MSU student, Faculty of Biology UG, defense of the master's thesis: 8^{th} July 2022
- Current experimental work on the impact of different concentrations of Zn and Cu on the survival rate of adult female ostracod *Heterocypris incongruens* from natural and laboratory populations – Anna Michalak MSU student, Faculty of Biology UG, planned date of master's thesis defense: July 2023
- Current experimental work on the impact of different concentrations of Zn and Cu on the dynamics and success of hatching in ostracod *Heterocypris incongruens* from the laboratory population – Klaudia Bartosik MSU student, Faculty of Biology UG, planned date of master's thesis defense: July 2023
- Current experimental work on the effect of different concentrations of Zn on the course of eggs laying and hatching, and on the number of larvae in the laboratory population of the ostracod *Heterocypris incongruens* – Dominika Gruba MSU student, Faculty of Biology UG, planned date of master's thesis defense: July 2023

Conducted lectures and classes (in Polish):

- *Academic Writing* – lectures and workshop classes for Genetics and Experimental Biology (GIBE) students
- *Baltic Sea Environment* – auditorium classes for Faculty of Biology and Protection of Natural Resources (OZP) students
- *Basics of Genetics* – laboratories for GIBE and Medical Biology students
- *Basics of Marine Ecology* – auditorium classes for Faculty of Biology and OZP students
- *Evolutionary Drivers of Biodiversity* – auditorium classes for OZP students
- *Fundamentals of Ecotoxicology* – lecture for OZP students
- *Fundamentals of Population and Conservation Genetics* – auditorium classes for GIBE students
- *General Genetics with Elements of Conservation Genetics* – laboratories for OZP students
- *Genetics* – laboratories for Faculty of Biology students
- *Information Technology* – classes for Medical Biology students
- *Molecular Ecology* – lectures for OZP students
- *Specialization Classes* – for Faculty of Biology students
- *Thesis Supervision Classes* – for Faculty of Biology and GIBE students

7. 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.

Anna Żyłkowska
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(Applicant's signature)