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## **Changes in the distribution of marine invertebrates in a warming Barents Sea over the last century.**

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I'd like to think she chose well.

## ***Abbreviations***

**BP** – Before Present  
**PC** – Principal Components  
**CA** –Correspondence Analysis  
**CMIP6** – Coupled Model Intercomparison Project  
**ESA** – European Space Agency  
**FAIR** – Findable, Accessible, Interoperable, Reusable  
**GBIF** – Global Biodiversity Information Facility  
**IHO** – International Hydrographic Organization  
**LMEs** – Large Marine Ecosystems  
**NAOI** – North Atlantic Oscillation Index  
**NPP** – Net Primary Production  
**PAME** – Protection of the Arctic Marine Environment  
**QGIS** – Quantum Geographic Information System  
**SSP126, SSP585** – Shared Socioeconomic Pathways  
**WoRMS** – World Register of Marine Species

# 1 Abstract

The Barents Sea is a shelf sea in the European Arctic and is influenced by the North Atlantic Current and the Arctic Ocean. The North Atlantic Current is composed of warmer, saline waters compared to the cold, fresher waters from the Arctic Ocean. Over the last century, the Barents Sea mean temperature has increased by 1.5°C above a depth of 60m and by 0.5-0.8°C below 60m. This warming is disproportionately high compared to other areas of the globe. A consequent loss of sea ice and changes in the salinity of the Arctic Ocean has been observed, especially since the 1980s. It is important to monitor distribution changes in marine invertebrates because they can reflect fluctuations of their environment and can potentially have strong impacts on the ecosystem. Marine invertebrates occupy many ecological niches and go through diverse life stages, including external fertilisation and often a planktonic larval stage. They are therefore dependent on environmental conditions both in the benthos (in case of seafloor dwellers) and the water column. For example, those with a planktonic life stage are distributed by marine currents and each species has a temperature and salinity optimum for their development. It is therefore expected that changes in the environment, such as increased ocean temperatures due to climate change, will lead to changes in the distribution of marine organisms. However, changes of invertebrates' distributions in the Barents Sea over the entire past century have not been studied yet and this is the objective of this study.

I used data mediated by the Global Biodiversity Information Facility (GBIF) to characterize species distributions and their potential change over more than a hundred years. The periods were separated into five blocks starting before 1900 and go until 2010. I took the acceleration of the warming past 1980 into account by shortening the later time ranges. The study area was divided into warm (south-western Barents Sea), mixed (central Barents Sea) and cold (North-eastern Barents Sea) zones based on bottom water temperature.

I found that, over time, distribution of invertebrates has changed in different ways. First, using a correspondence analysis, I visualized similarity patterns in taxon occurrences among time period-region groups. Depending on the geographical zone in the Barents Sea some invertebrate distributions were similar in their temporal spatial pattern up until a turning point. In the cold and mixed zones, for instance, that turning point was 1980, where afterward I could observe a drastic change in species composition patterns. In the southern area in contrast, I found a consistent, more gradual change through time. Then we used a log-linear model to analyse changes in number of occurrences, accounting for changes in observation pressure. Overall, out of 364 species investigated across 11 phyla with a Log-linear model 71% of them and all but one phylum presented a change of taxon occurrences in at least one period. Changes of the distribution of marine invertebrates are discussed based on changes in their spatial occurrence patterns and difference of the number of occurrences compared to before 1900. For instance, two arctic species, *Stegophiura nodosa* and *Ophiocten sericeum*, significantly decreased in number of occurrences in 1900-1950 and 1980-2000, respectively. Other notable species are boreal mollusc, *Cuspidaria lamellosa* and *Euspira montagui*, who increased in occurrences consistently after 1950, but also show a movement north in their distribution on a map of the Barents Sea. In conclusion, the species composition of invertebrates in the Barents Sea has shifted in its recent history, most likely due to the warming waters caused by climate changes.

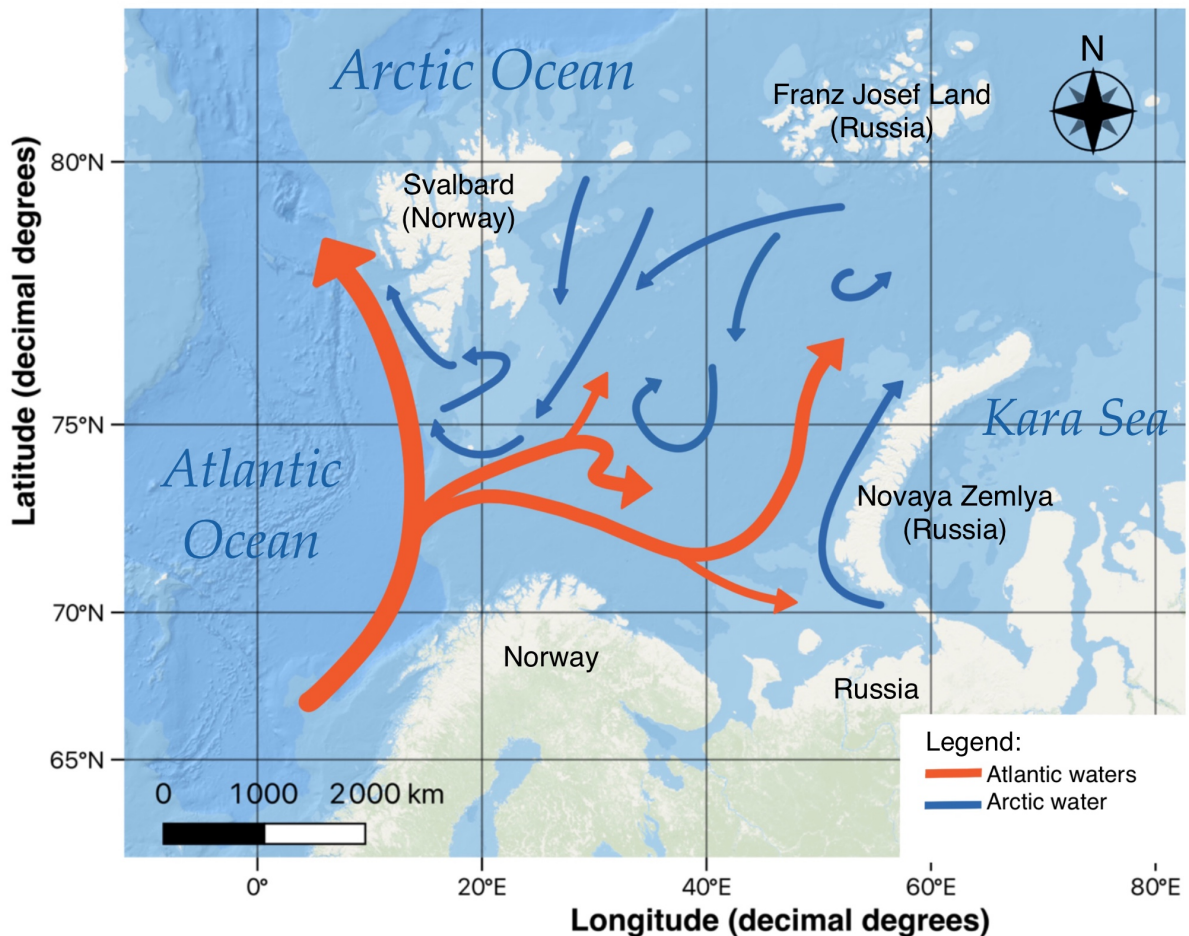
## 2 Introduction

The Arctic Ocean is warming at an alarming rate. Arctic Amplification is a phenomenon where the Arctic is warming up faster than the rest of the globe due to sea ice loss, at a rate nearly four times faster between the years 1979 and 2021 (Rantanen et al., 2022). The Barents Sea is particularly affected by the Arctic Amplification, with warming speeds seven times higher than the global average recorded, e.g., along the coast of Novaya Zemlya (Rantanen et al., 2022). We are now aware that warming in the water can be a factor that contributes to shifts of distribution in marine species (Hastings et al., 2020). Although, to some extent, invertebrates are capable of adapting to diverse ecosystem changes their acclimatisation is not a large enough cushion against the negative impact of a temperature change in their environment (Hastings et al., 2020). Due to this, there is a lot of attention on Arctic marine species and their possible disappearance due to their thermal habitat shrinking. However, there are few studies available that have investigated changes of distribution of marine invertebrates in the Barents Sea. The objective of this thesis is to provide knowledge on past and current invertebrate species distributions in the Barents Sea, which will be important in predicting future change in the region.

### 2.1 Physical oceanography and shifting condition of the Barents Sea

The Barents Sea holds a key position in the Arctic Ocean. It is located north of Norway and Russia, west of Novaya Zemlya, delineated to the west by the shelf break and goes north past Svalbard. The Barents Sea is separated into two main ecosystems. The north is influenced by Arctic Ocean waters (Fig. 1), which are colder and lower in salinity than Atlantic Waters, it is also more stratified and has a seasonally ice-associated ecosystem (Lind et al., 2018). The south has a warmer Atlantic climate (Fig. 1), the waters are higher in salinity, seasonally well-mixed and with more nutrients, making it a richer ecosystem in terms of productivity, and diversity of species. Both water masses meet at the Polar Front, mix to some degree, and create a unique environment and ecosystem (Lind et al., 2018; Loeng, 1997).

The Barents Sea is a comparatively shallow continental shelf sea, with an average depth of 230m, the maximum depth is found around Bjørnøyrenna at 500m, and the shallowest part is near Spitsbergenbanken at 50m. Hence the bottom topography has a big influence on the currents throughout the water column (Loeng, 1991).



**Figure 1:** Main input of warm and cold waters into the Barents Sea and its surrounding waters, based on Asplin et al. (2001).

The transport of warm water by the North Atlantic Current is essential for the warm climate of the Barents Sea (Asplin et al., 2001). Consequently, if the increase of temperature continues, a shift to an Atlantic dominated climate in the entirety of the Barents Sea is possible (Lind et al., 2018). Namely, in 2004 the Barents Sea experienced a warming shift (Lind et al. 2018). Since then, several additional marine heatwaves have been identified (Lind et al., 2018; Mohamed et al., 2022). A marine heatwave is defined as a fixed period of abnormally high temperature compared to the usual mean for the season and area (Mohamed et al., 2022). The annual mean of marine heatwaves, their frequency, days, and duration have all increased respectively by 62%, 73% and 31%, from before to after 2004. Marine heatwaves are detrimental to the health of the marine ecosystems (Mohamed et al., 2022). They can raise the mortality rate of benthic invertebrates communities (Garrabou et al., 2009) either by reducing the levels of surface chlorophyll in the ocean (Bond et al., 2015), participating in loss of seagrass meadows and kelp forests (Arias-Ortiz et al., 2018; Thomsen et al., 2019) or increasing the frequency of harmful algal blooms (Trainer et al., 2020). The recent records of strong marine heatwaves in the Barents Sea are concerning as more than half of all the “marine heatwave days” were recorded between 2011 and 2020 (Mohamed et al., 2022). During the heatwave of 2016, for example, the intensities, based on the mean average temperature for the season, were around 1.55°C and 1.85°C and the maximum intensities were approximately 2.15°C and 2.29°C in the Northern Barents Sea and the Southern Barents Sea, respectively. Not only short heatwaves are observed, but furthermore since 2004 Sea Surface Temperature has increased in the Barents Sea by  $0.25 \pm 0.18^\circ\text{C}$  per decade in the

North and  $0.58 \pm 0.21^\circ\text{C}$  per decade in the South (Mohamed et al., 2022). Hence the ever faster warming of the Arctic Ocean, and the Barents Sea specifically increased the focus on this geographic region in the recent decades.

Nevertheless, the acknowledgment of a shift in the climate is not new to the 21<sup>st</sup> century. Scientist all around the world were already monitoring our ecosystems back in the 20<sup>th</sup> century. The Atlantic surface temperature between 1940 and 1970 were compared to the mean temperature of the 90s and a significant increase in temperature was recorded (Grotefendt et al., 1998). Although at the time the authors attributed their finding to a decadal fluctuation we know, now, that the shift was not temporary and that it has worsened with time (Grotefendt et al., 1998; Rantanen et al., 2022).

As evidenced by the Arctic amplification phenomenon the degree to which ecosystems are affected by global warming is not uniform on Earth, neither geographically nor throughout the water column. The air and surface layer of the water in the Barents Sea presents a strong rise in temperature within the last century in contrast to bottom water, where changes also occur but are dampened. Still, for the decade 2000-2010 a mean bottom temperature of 1.0 to 1.5°C above the 1951-2000 normal is reported (Boitsov et al., 2012).

Overall in the Barents Sea, in addition to a change in the mean temperature of the water, an increase in the CO<sub>2</sub> uptake and a loss of sea ice are also reported (Smedsrud et al., 2022). Increased CO<sub>2</sub> uptake is the primary cause of ocean acidification (Csapó et al., 2021; Monitoring, 2018). Moreover, since the 1970s Arctic sea-ice extent has decreased by 10% per decade. The presence of sea-ice is essential for the Arctic marine ecosystem as many organisms live underneath or even inside the ice (Comiso, 2002; Comiso et al., 2008) and sea-ice modulates food supply quantity, composition and quality (Cautain et al., 2022). Therefore, the monitoring of sea-ice, its extent and thickness is an important research topic. The European Space Agency's CryoSat-2 altimeter radar report from 2021 shows that in the decade of 2011 to 2020 the Arctic sea-ice was on average  $1.87 \pm 0.10\text{m}$  in May and  $0.82 \pm 0.1\text{m}$  in August, respectively, at the start and the end of the melting season, showing a decrease of ice thickness over the past decades (Landy et al., 2022).

A consequence of the warming is that the Barents Sea is predicted to potentially be ice-free during the summer before 2050, and year-round ice-free during the 2050's (Årthun et al., 2021). The prediction was generated using two Shared Socioeconomic Pathways SSP126 and SSP585 scenarios (Gidden et al., 2019) of the Coupled Model Intercomparison Project (CMIP6) model (Eyring et al., 2016). The scenarios SSP126 and SSP585 represent a low-emission and a high-emission future where strong economic growth is run by sustainable energy versus fossil energy, respectively (Gidden et al., 2019). The described environmental changes are likely to have affected, and continue to affect, species distribution patterns.

## **2.2 Environmental conditions as a critical factor for marine invertebrate distributions**

Invertebrates are a paraphyletic group of animals with very different life cycle stages (Nekhaev & Krol, 2017). Paraphyletic means most but not all taxa in question are the descendants of a common ancestor, as opposed to monophyletic where all taxa in questions are descendants from the common ancestor. Most invertebrates have a short lifespan

compared to vertebrates and follow a R reproduction strategy, which involves many offspring and no parenting (Allmon & Hendricks, 2021). R-K categories, though, are extremes and life history strategies rather follow a continuum based on body size, environment temperature and food availability. However, in the cold waters and high latitudes of the Arctic longevity tends to be higher. It is not uncommon to encounter invertebrate decades or a century old, for instance *Strongylocentrotus pallidus*, a sea urchin, was found to have a maximum age of 42 years (Bluhm et al., 1998), and even larger, and therefore likely older, specimens were observed. This is opposed to sea urchins from boreal regions which are estimated to live for one or two decades (Bluhm et al., 1998; Gage, 1991; Guillou & Michel, 1993). *Hiatella arctica*, a mollusc, can live up to a century (Sejr et al., 2002). Two brittle stars, *Ophiura sarsii* and *Ophiocten sericeum* have a maximum age of, respectively, 27 and 20 years (Sejr et al., 2002). It is common for invertebrates to have a planktonic larval life stage, between fecundation and metamorphosis. This leads to a dependence of their distribution on marine currents (Berge et al., 2005). Their chances of survival in the area where the larvae settle, in the case of taxa where adults are benthic, is largely determined by physical factors of the environment (Allmon & Hendricks, 2021).

A few factors relating to marine invertebrates make them a great indicator of change and, hence, a good group to monitor. Firstly, as previously mentioned, their planktonic live cycle stage allows a greater potential geographic distribution range, as opposed to a non-planktonic species. Consequently, their capacity of being widely distributed by ocean currents before settling (if benthic) makes them great indicators of changes in their environment (Allmon & Hendricks, 2021). Secondly, some will become sessile as adult, or have a low mobility which make them a suitable group for long term comparative studies, where we can investigate the effect of environmental change on communities over a long period of time (Zakharov et al., 2020). Lastly, data shows that marine species are more sensitive to isotherm shifts than terrestrial species, in fact they are six times faster in their move toward the Arctic pole (Lenoir et al., 2020).

Those characteristics make marine invertebrates the topic of many studies on biotic communities and their response to environmental change. Reports in the Black Sea, for example, found a shift of marine species distribution and the composition of the benthic community, with evidence suggesting a correlation between the rise in the sea surface temperature and the spread of alien marine species (Snigirov et al., 2013). Also, in the Barents Sea and its adjacent waters, four species of gastropods previously unreported in this location have been found, evidence suggesting that gastropods are shifting further east as well as north (Kantor et al., 2008; Zakharov & Jørgensen, 2017). Another study, this time global, used 230 species of marine invertebrates, as well as fishes, and a dynamic bioclimate envelope model to create a future projection for 2050. The conclusions were the highest amount of species invasion is taking place in the Arctic and the numeral extinction of species in the sub-polar region (Cheung et al., 2009).

Species distribution range shifts are likely different among taxa of diverse biogeographic affinities. In the Northern hemisphere species are characterised as boreal, Arctic-boreal, or Arctic depending on their distribution. Typically, the Barents Sea is composed of Boreal and Arctic species. A study based on fish data from 2005 to 2017 showed that the Northern and Eastern parts of the Barents Sea are most commonly dominated by Arctic species while the Southern and Western areas are dominated by boreal species (Johannesen et al., 2017). Not all species found in the northern Barents Sea, however, are purely Arctic in their distribution, although most share a cold-water affinity and can be defined as Arctic-boreal (Degen et al.,

2016). Climate change and the warming of the Arctic is prone to push the geographical boundaries between Arctic and boreal regions north-eastward in the Barents Sea (Jørgensen et al., 2014).

Out of all marine invertebrates some sub-groups draw particular attention, such as those inhabiting the benthos including for example Mollusca. Marine benthic invertebrate communities in the Barents Sea constitute a significant part of the total biomass (Zakharov et al., 2020). As with fish, benthic invertebrate community distribution follows the water mass distribution in the Barents Sea (Degen et al., 2016). The Barents Sea benthos is composed of various taxonomic groups, of which, based on their secondary production, the most abundant phylum of the megabenthos (the larger, >4mm, benthos caught in trawl nets) is Echinodermata, responsible of 50% of the production, followed by Arthropoda and Annelida with respectively 18% and 12%. By biomass (mg C m<sup>-2</sup>) Echinodermata are still the leading phylum in the Barents Sea with 61%, followed by Arthropoda with 14% (Degen et al., 2016). Methodological differences can affect the conclusiveness of these data. When the smaller macrobenthos is also considered Mollusca dominated 35% of the total community abundance followed by Echinodermata with 19% and Arthropoda with 15% (Wassmann et al., 2006). Megabenthic secondary production is higher in the North of the Barents Sea, the area seasonally covered by sea-ice than in the south, the ice-free region (Degen et al., 2016). Mollusca and other taxa forming hard-structures prove to be valuable groups as most the hard-structures survive them after their passing, making it easy for us to prove the presence of an individual in an area even if the individual is no longer alive (Nekhaev & Krol, 2017). On the other hand, non-shell forming invertebrates can only be recorded when observed alive or after fixation.

Climate change affects various features of an ecosystem in which the effect can be amplified as species interact together in a network. There is a trophic relationship between species in an ecosystem, and they influence and are influenced by their environment. The distribution of organisms present in the Barents Sea is a reflection of the climate gradient (Nascimento et al., 2023). Therefore, changes in the climate can affect the entire ecosystem (Peura et al., 2013). A common effect of an alteration in the ecosystem is a change in species' distribution. Climate change being responsible for a shift in species' distribution has been observed several times in the northern hemisphere, mainly in the North Atlantic (Hastings et al., 2020). For example, in Ireland, a study demonstrated that climate change had an effect on the intertidal biota. The authors reported that five northern species had decreased in abundance between years 1958 and 2003, supporting their hypothesis of a climate-driven effect on species distributions, increasing southern species and decreasing northern species (Simkanin et al., 2005). Another example is in Svalbard, in my study area, where a species of mussel, *Mytilus edulis* had not been observed in a millennium until the early 2000's (Berge et al., 2005). *Mytilus edulis*' shells found in sediment or washed ashore are closely monitored and carbon dated in Svalbard (Salvigsen, 2002). The reappearance of the mussel is likely due to the rise of surface water temperatures and the North Atlantic current which transported the larvae to the coast of Svalbard (Berge et al., 2005). Also in my study zone, near the coast of Murman, specimens of the snail *Aporrhais pespelecani* were found, although this location is extremely far east of their usual distribution, since the previous easternmost finding was northern Norway, 950km west of the Murman coast. However no juveniles were found and therefore it cannot be proven that the snails can reproduce and maintain a viable population in the area (Kantor et al., 2008).

## 2.3 Study objectives and hypotheses

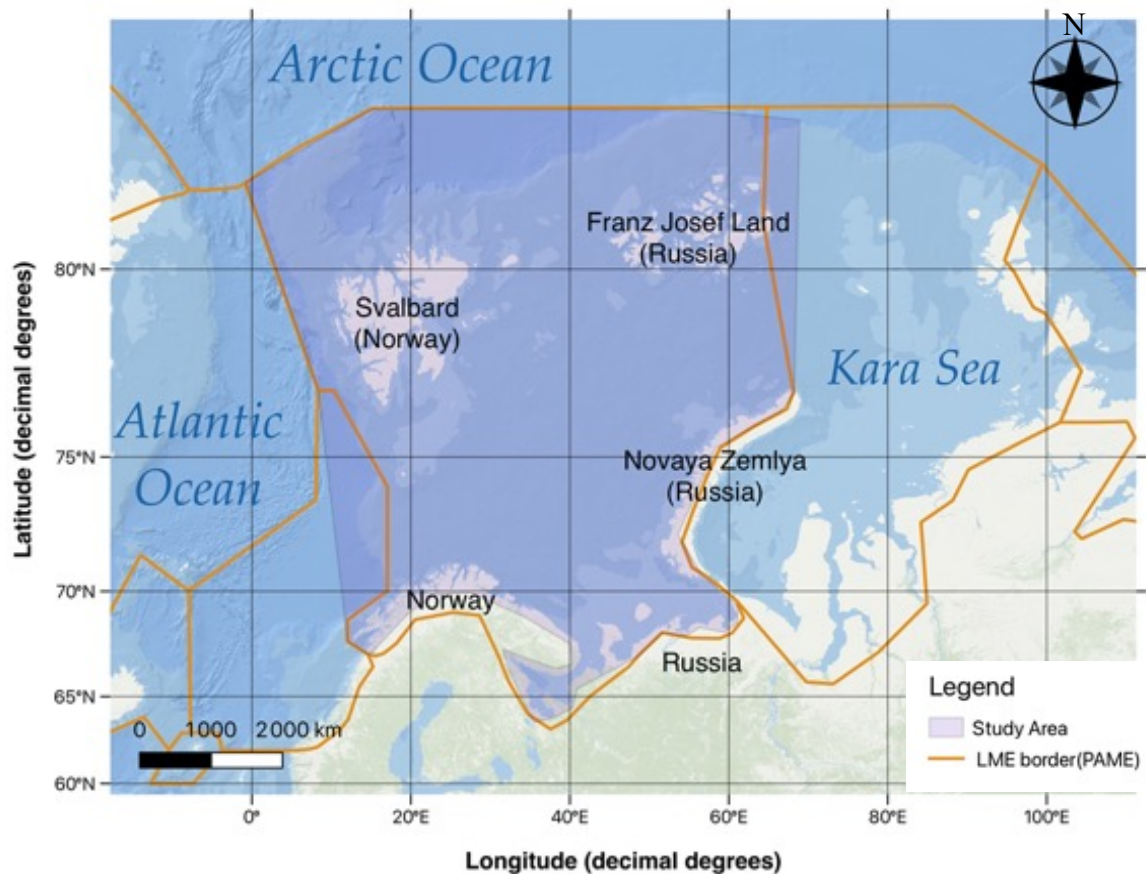
The objective of this thesis is to analyse if the distribution of invertebrates in the Barents Sea has changed in the past century. Specifically, my goals were to uncover temporal patterns of distribution change, to infer distribution change from effort-corrected changes in number of observations in defined regions through time, and to contrast detailed distribution changes for selected Arctic versus boreal species. I hypothesised that following the increase of climate change-driven warm water inflow into the Barents Sea over time, invertebrates that are adapted to warm Atlantic waters should become more common in the Barents Sea over time.

## 3 Materials and Methods

### 3.1 Study Area

While the boundaries of the Barents Sea are coarsely consistent, several slightly differing polygons have been used by diverse organizations such as IHO (International Hydrographic Organization) or PAME (Protection of the Arctic Marine Environment). Therefore, it was necessary to define our own set of borders when studying the area. Data collections, such as GBIF (Global Biodiversity Information Facility), and programs, like RStudio and QGIS (Quantum Geographic Information System) do not have geographical borders built in, they require the user to input set coordinates, here a multi-polygon, to work within the study area. For this thesis, a large polygon was drawn with set coordinates using the program QGIS (Fig. 2), the total area is 2 608 670 km<sup>2</sup>, however, whilst the polygon englobes land, we will only consider marine species.

The study area delineation is based on PAME's Large Marine Ecosystems (LMEs) and their definition of the Barents Sea, updated in 2014 (Fig. 2). To have a diverse group of species, with different life stages, deep water species were relevant in this study. Hence the study area was slightly expanded in the Southwest and Northeast.



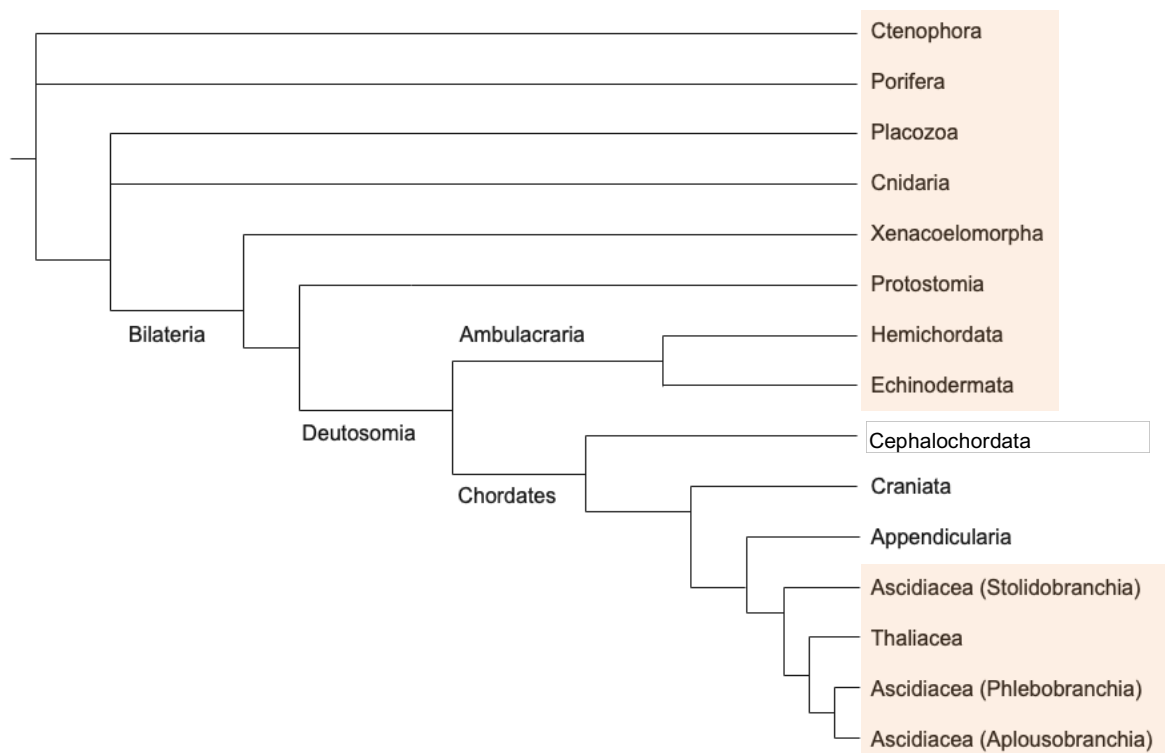
**Figure 2:** Study Zone in comparison to Protection of the Arctic Marine Environment's (PAME) Large Marine Ecosystems (LME). In purple is the polygon used for this paper, in orange are the border set by PAME's LMEs.

### 3.2 Data acquisition

The primary source of taxon distribution data used in this study was GBIF. GBIF is an international organization created to make species distribution data and tools to extract them available online. GBIF is a tool that facilitates the compliance to the FAIR guidelines (Findable, Accessible, Interoperable, Reusable) (Wilkinson et al., 2016). Those guidelines are there to enable other scientists to reuse data for analyses (Wilkinson et al., 2016). GBIF's portal allows anyone to research distribution or taxonomic data on thousands of species, such as plants, animals, fungi, and microbes. Some of GBIF's tools serve to compile and share one's data under a unique language (Darwin Core [DwC]) in order to facilitate partnerships as well as create a data format that facilitates analysis of data originating from multiple data providers. Other of GBIF's tools can be used to check global trends and relative species' trends observations. GBIF is one of the biggest online collections of species occurrences globally. The data shared on GBIF comes from universities, citizens, companies, taxonomic specialists, and scientists across the globe. However, sampling effort, data storage and open access capacities are uneven due to nations' differences in funding and data sharing in science which can then result in biases in their contribution to GBIF (Beck et al., 2014).

Additionally, the software R (R Development Core Team, 2010) was used to acquire and clean the taxon distribution data as well as run statistical tests. Using R, and the package *rgbif*

(Chamberlain & Boettiger, 2017) all occurrences of metazoans in the Barents Sea were downloaded from GBIF for each time frame as defined below (GBIF.org, 2023a, 2023b, 2023c, 2023d, 2023e). As previously mentioned, invertebrates are a paraphyletic group. Therefore, in online collections such as GBIF there is no ‘invertebrates’ class to isolate. Due to this, for this thesis, I defined as invertebrates all descendants of Metazoans excluding vertebrates. Each individual occurrence download from GBIF comes with its metadata, information about the species, the exact coordinates where the specimen was found and when. Using these metadata and R, the data frames were cleaned to obtain all invertebrates in our study zone, separated by five data periods as explained below. In other terms, all chordates, apart from the invertebrate groups (Ascidiacea and Thaliacea; Thaliacea were not reported), were removed from the databases of metazoans (Fig. 3). Due to a coding error during the initial cleaning of the dataset, Arthropoda were excluded from the dataset.



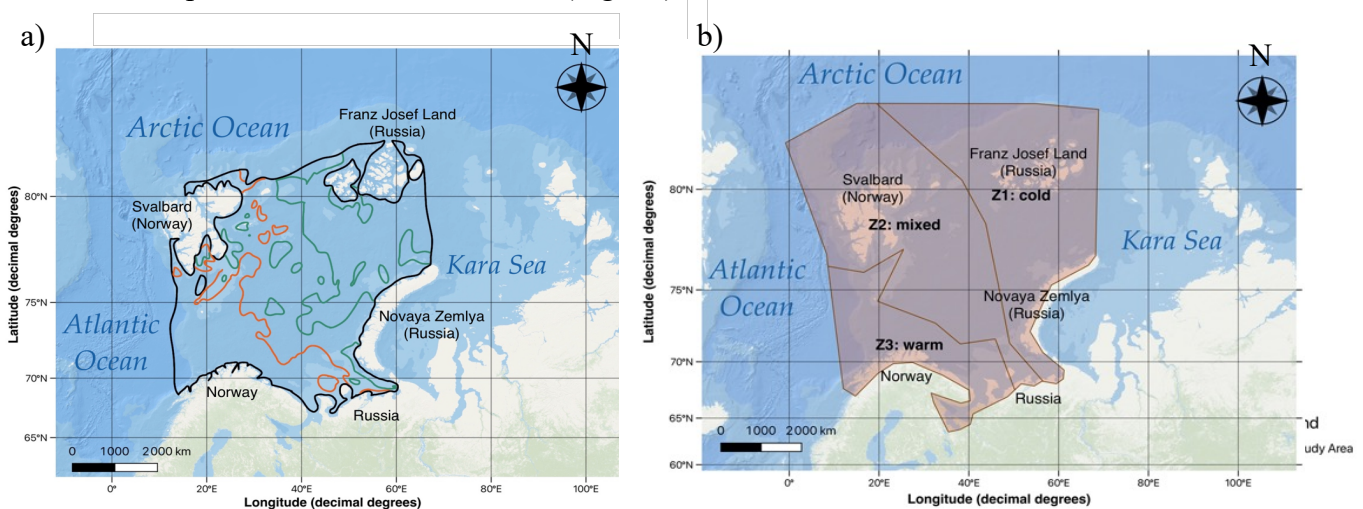
**Figure 3:** Animal phylogenetic tree showing in orange the selected taxa for this study. Built using data extracted from Braun et al. 2020, Franchi et al. 2017 and Giribet and Edgecombe's book "The Invertebrate Tree of Life" (Braun et al., 2020; Franchi & Ballarin, 2017; Giribet & Edgecombe, 2020a, 2020b) who themselves summarize diverse works (Braun et al., 2020; Edgecombe et al., 2011; Eernisse et al., 1992; Fortunato et al., 2014; Giribet et al., 2001; Meglitsch & Schram, 1991; Peterson & Eernisse, 2001; Regier et al., 2010; Schmidt-Rhaesa et al., 2015; Smith, 1911; Zrzavý et al., 1998)

Afterwards the datasets were processed and compiled into one following the criteria of selection (see below). QGIS was used to visualize some of the species' distributions on a map.

### 3.3 Data parameters

#### 3.3.1 Geographical and temporal criteria

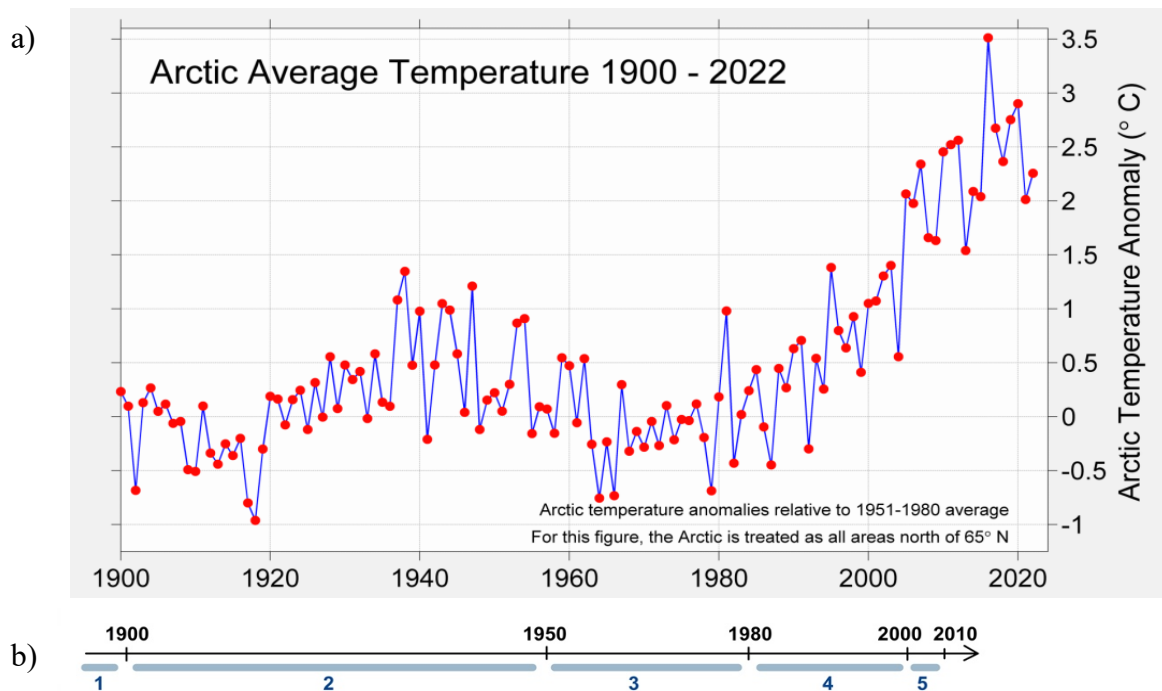
For statistical testing of potential invertebrate distribution changes, the study area was separated into three zones based on the mean water temperatures given in Skagseth et al. (2020), from their map of 2004-2018 data (Skagseth et al., 2020) (Fig. 4a). Each zone was given its own polygon with set coordinates and named. “Z1: cold”, 993 141km<sup>2</sup>, contains the water with a mean temperature between -2°C and 0°C, i.e. Arctic waters low in salinity, “Z2: mixed”, 675 733km<sup>2</sup>, ranges between 0°C to 2°C is a result of the mixing of Arctic and Atlantic waters and “Z3: warm”, 939 795km<sup>2</sup>, consists of Atlantic waters, high in salinity with a temperature between 2°C to 4°C (Fig. 4b).



**Figure 4:** Map of the Barents Sea including a) mean near-bottom temperature for the periods 2004–2018 from Skagseth et al. (2020). Black outline shows the limits of the study area, orange and green lines represents the temperature limits of 2°C and 0°C respectively; b) study Area separated in three zone according to the temperature block -2°C-0°C (Z1), 0°C-2°C (Z2) and 2°C-4°C (Z3) of a). In shaded orange the polygon used for this study, the orange lines going through it show where the delimitation for each zone is.

The number of occurrences of a given species in the warm, mixed, and cold zones through time is compared as an indication of whether a significant difference in the distribution of invertebrates occurred.

This study covers all available taxon occurrences in GBIF for the Barents Sea until 2010. The occurrence records were separated into five periods, taking into consideration the increase of temperature in the past 40 years (Fig 5a). The periods are “pre-industrial age” before 1900, 1900 to 1950, 1950 to 1980; past the 1980’s the temperature increased much faster; therefore, the length of the periods is reduced accordingly to 1980 to 2000 and 2000 to 2010 (Fig 5a, b).



**Figure 5:** a) Berkeley Earth's Global Temperature report for 2022, Arctic Average Air Temperature 1900-2022 (<https://berkeleyearth.org/global-temperature-report-for-2022/>). b) Timeline of the study's period. In blue the five periods used in this study; 1 represent "before 1900".

### 3.3.2 Selection criteria for species

A few key criteria were selected when cleaning the data. First, the limits for this study were set at a minimum of 10 occurrences for a given taxon in one period. In taxonomy misidentification can happen, therefore it is important to have multiple occurrences of the same species in the same region to assume as a fact the presence of the species in this area. Having a few specimens out of their usual distribution zone is not representative of the species' distribution. Second, a species had to be present in the area for at least five years to be considered. This ensures that the community is settled and established in the location and not transient. Five years was estimated to be sufficient time to have several generations, considering the lifespan of most invertebrates, their typically annual reproduction and high number of offspring per season. Finally, occurrences after 2010 were not used, although material is available on GBIF. This limit was chosen due to multiple factors. One of those factors is the theory of a species accumulation curve. This predicts that as the sampling effort in a given area increases, so would the cumulative number of species found until the sampling effort is large enough to flatten the curve and no more new species are added. This theory implies that a high number of sampling over a long term period is necessary to obtain an accurate picture of the distribution of a species in the same zone (Cam et al., 2002; Colwell & Coddington, 1994; Colwell et al., 2004; Fisher et al., 1943). For example, for fungi in Norway, using open data found on GBIF, one would need to consider at least 30 years of accumulated open source data to obtain a stabilized curve of distribution (Yu et al., 2022). Another factor was the time between an observation done in the field and its publication on an open source collection. Expeditions usually acquire many specimens. Those are then sorted, processed, identified and eventually published and shared online, although the last point is not always obligatory yet (Wessels et al., 2014). The full process can take a few month to years, even decades, therefore the analysis of recent samples could still be ongoing. Some open

source database are published with the goal of being updated with time. The Gastropoda collection from the The Arctic University of Norway published on GBIF, for example, was made public in 2022. Since then it has been updated monthly with, as of 1<sup>st</sup> March 2023, above 15 000 occurrences. The temporal range of observations go from January 1844 (oldest from Norway June 1876) to September 2021 (Altenburger & Bergersen, 2023). Limiting ourselves to occurrences observed before 2010 gives us better odds to have the complete picture with a flatten curve of species accumulation and limits the compromization of our findings.

## 3.4 Data processing

### 3.4.1 Data cleaning and data frame set up

The datasets of species occurrences, one per each of the 5 periods, downloaded from the GBIF servers were cleaned as follows: species that were recorded less than 10 times were removed from the corresponding period database. This criterion was applied to each period database independently, meaning a species could have more than 10 occurrences in “before 1900” and stay in the dataset but then, for example, only be recorded twice in “1900-1950” and be removed from the dataset “1900-1950”. Then species that were not identified to species, i.e., *Buccinum* sp., were also removed. Afterward each dataset was compiled into one named ‘df\_model’. Columns were created and named for each period as follows, total raw occurrences ‘N’, relative occurrences ‘R’, calculated using the total number of observations for the period, and raw occurrences per zone (“Z1:cold”, “Z2: mixed”, “Z3:warm”).

Different columns were used to run both the Correspondence analysis (CA) and the log-linear models. The raw occurrences per zone of ‘df\_model’ combined with the multi-polygon coordinates from the ‘barents’ shape file were used to run the correspondence analysis (CA) described in 3.5.1. The same columns were isolated by individual rows for the log-linear models described in 3.5.2. However, the absences of data (marked NA) in the datasets due to the selection criteria needed to be turned into zeros in order to use the statistical tests. It is important to keep in mind that those zeros do not represent a confirmed absence of the species, only the lack of observation on GBIF that agree with the criteria. The first 11 columns, ‘N’ and ‘R’ were used to model the diverse histograms and figures. Additionally, [WoRMS](#) taxon match was used to add phylum and class to the various excel sheets used to create the charts.

### 3.4.2 Artefacts

The results of the CA for each individual species (details in 3.5.1) were investigated, taking note of any changes of distribution possible, and in which zone species were mostly present. This table was checked against an “Atlas of the Megabenthic communities in the Barents Sea and its adjacent waters” built with a cooperation between Norwegian and Russian researchers from 2018 (Zakharov et al., 2018). This crossover gave evidence of potential artefacts in my datasets: species that show a different distribution in the data available online compared to occurrences published in the scientific literature. Artefacts can be induced by incomplete or poor representation on the data acquired on GBIF. Out of 438 species 21% showed a similar distribution between GBIF and the Atlas, 16% showed a different distribution. However, 62%

of our species were not present in the Atlas. This cross referencing led to the removal of 73 species from our database, species who presented a different distribution in the literature than what we observed in our dataset. The correspondence analysis was run once again on the data frame without artefacts and the patterns observed previously were still present.

### 3.4.3 Biogeographic affinities

The five species with the highest number of observations in each time period were combined into a table. The total of 25 species were then researched to sort them into ‘Arctic’, ‘Boreal’, ‘Arctic-Boreal’ or ‘Cosmopolitan’ biogeographic affinities using literature (Brotskaya & Zenkevitch, 1939; Ekman, 1953; Fossheim et al., 2015; Loeng, 1991; Wassmann et al., 2006). However, with the classification of Arctic, boreal and cosmopolitan comes some subjectivity from one author to another, as the zoogeographical border are arbitrary to some degree (Ursin, 1960). Some known Arctic species that could be interesting to look further into were also added to the table. Maps showing spatial distribution were then made using QGIS to observe any pattern in those species.

## 3.5 Statistical analysis

### 3.5.1 Correspondence analysis

Statistics were run using the software R. The R package *ade4* (Thioulouse et al., 2018) was used to run a correspondence analysis (CA) of all species’ occurrences sorted into geographic zones for each data period (Appendix: Df\_model dataset, part 2: Occurrences sorted by zone following the Study Zone multi-polygon). A CA is built on the principal component analysis (PCA) for positive data such as number of occurrences. It is a method for the construction of ordination of multivariate ecological data. It analyses the difference between relative values (i.e. proportions), here the number of observations of a species in diverse “period · zone” classification (Greenacre & Primicerio, 2014). The lines represent the species, and the columns are “period · zone”. I ran the CA, where I showed different data labels in different panels and figures. This CA maps any similarity patterns among taxon occurrences in data period-region groups that may be present in the dataset. The ordination by data “period · zone” groups and taxa associated with them should be read together. The CA of the period by region (Fig. 7a.) and the CA of all the species that are associated with specific “period · zone” (Fig. 7b.) should be read together. Each label represents the mean of the distribution of the variable chosen, therefore if two labels are close to each other their taxon occurrences are similar. Correspondence analysis can also be called reciprocal averaging, since in the figure 7a, the site is at the average of the species they include and in figure 7b, the species are the averages of the site they are found in with a shrinking factor given by the eigenvalues of the CA axes. The CA with all the species was hard to decipher and was therefore replicated with labels showing each species individually, for which a subset is shown in the results (Fig. 11, 14, 16). The three renditions of the CA were colour coded to aid the comprehension, “Z3: warm” in pink, “Z2: mixed” in blue and “Z1: cold” in yellow. In the CA 7b, the label of the species are the means of the zone they are found, the colour code was replicated to observe if some species were specific to certain location. Using the `summary()` function the Principal Components (PCs) were noted down, in a CA difference along the PC1, or X axis, are stronger than differences along the PC2, or Y axis for an equal vectorial distance.

### 3.5.2 Log-linear modelling of species occurrence count

In order to test if changes in occurrences were significant multiple log-linear models were done, with and without an offset. A log-linear model is a generalized linear regression model. The log-linear models were run with “period” and “zone” as additive predictors.

An offset was included to account for sampling efforts (Warton, 2022). An offset is a data-item included in Poisson and Quasi Poisson function; it can vary for every data-record. In other terms an offset is a variable for which the regression coefficient is forced to be equal to 1 (Boshuizen & Feskens, 2010), as shown below.

$$\log(N_i/N_{tot}) = \text{Period} + \text{Zone} \text{ or,}$$

$$\log(N_i) = \log(N_{tot}) + \text{Period} + \text{Zone,}$$

*log(N<sub>tot</sub>) is then the offset with a coefficient = 1*

The offset is the total amount of observations per “period · zone”, named “ntot\_perzon” (Table 6). It allowed us to add the pressure of observation into the test. To evaluate the sensitivity of the log-linear results to the unequal observation density, log-linear models were also run without offset and later results from both were compared.

```
> ntot_perzon
<1900 Z1 cold  <1900 Z2 mixed  <1900 Z3 warm  00-50 Z1 cold  00-50 Z2 mixed
      130          1195          1821          1474          1625
00-50 Z3 warm  50-80 Z1 cold  50-80 Z2 mixed  50-80 Z3 warm  80-00 Z1 cold
      6048          150          686          4114          469
80-00 Z2 mixed  80-00 Z3 warm  00-10 Z1 cold  00-10 Z2 mixed  00-10 Z3 warm
      1971          8998          2          1449          28772
```

**Table 6:** Offset as used in the log-linear models on RStudio. For each “period · zone” group, the number used as offset is given underneath the name of the “period · zone”.

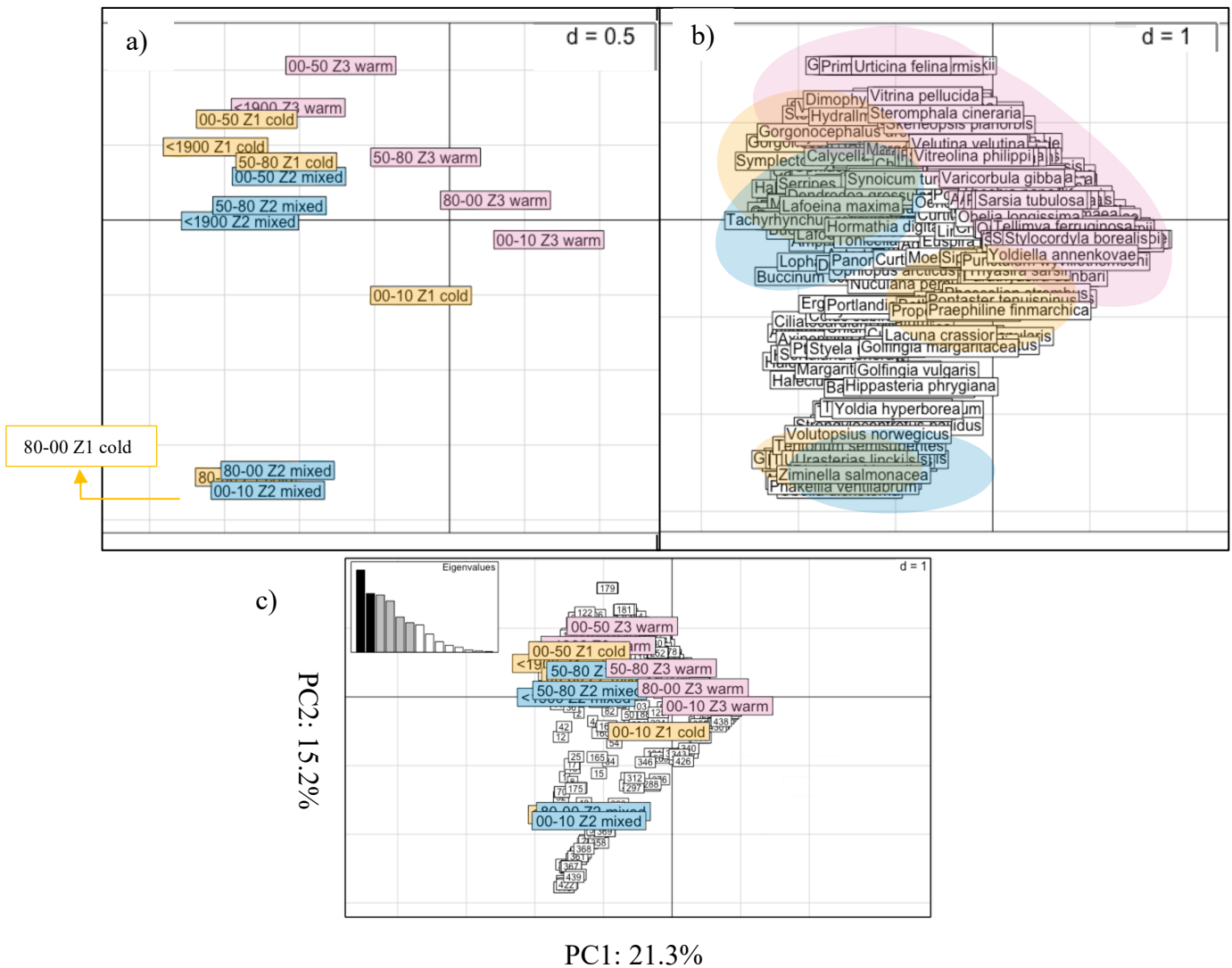
For species that had no occurrences in some zones and hence no reference point for the analyses, I used the following procedure: if there was no occurrence in the cold zone, I used the mixed area; for species that had no occurrence in the cold and mixed zone, I used the warm zone. This had no influence on the results because I compared changes among periods not among regions. To account for over-dispersion “Quasi-Poisson” tests were done. A Poisson distribution for the counts assume that the variance is equal to the mean, but this is often not the case. "Quasi-Poisson" assumes that the variance is proportional to the mean and is one way to analyse over-dispersed counts (Warton, 2022). Overall, 85% of the species were analysed using a Quasi-Poisson test. Each species was tested and interpreted individually, both with and without the offset, the results were then compiled in a table (Appendix: table log-linear model Result).

## 4 Results

### 4.1 Correspondence analysis: shifts in community composition

The correspondence analysis (CA) showed clear patterns of change of occurrences over time (Fig. 7a). The PC1 of the CA of all taxon occurrences per period and zone explained 21.3% of the variability and PC2 explained 15.2% (Fig. 7c). In detail, these patterns of change differed among the three zones. All zones occupied the same quadrant in the CA ordination in the periods before 1900, indicating similar species composition. In 1900-1950 all three zones' pattern were still located in the top left quadrant. Meaning their species' composition were similar but not identical. The cold and mixed zones in 1900-1950 and 1950-1980 indicate similar, yet not identical, occurrence patterns as in the previous period. In the warm zone, seen in red, however, each period had a distinct occurrence pattern unlike each previous period. The community shifts were most substantial after 1980-2000 and abrupt, with a switch towards the bottom left quadrant of the CA in the cold and mixed areas. The community in the warm zone steadily moved toward the bottom right quadrant until 2000-2010 indicating a change in species distributions and community composition. From 2000, the cold zone's species composition shifted substantially, while the warm zone's species' composition stayed similar from 1980-2000 to 2000-2010. In the period of 2000-2010 the cold species' occurrence pattern was closer to 2000-2010 warm than mixed in the ordination.

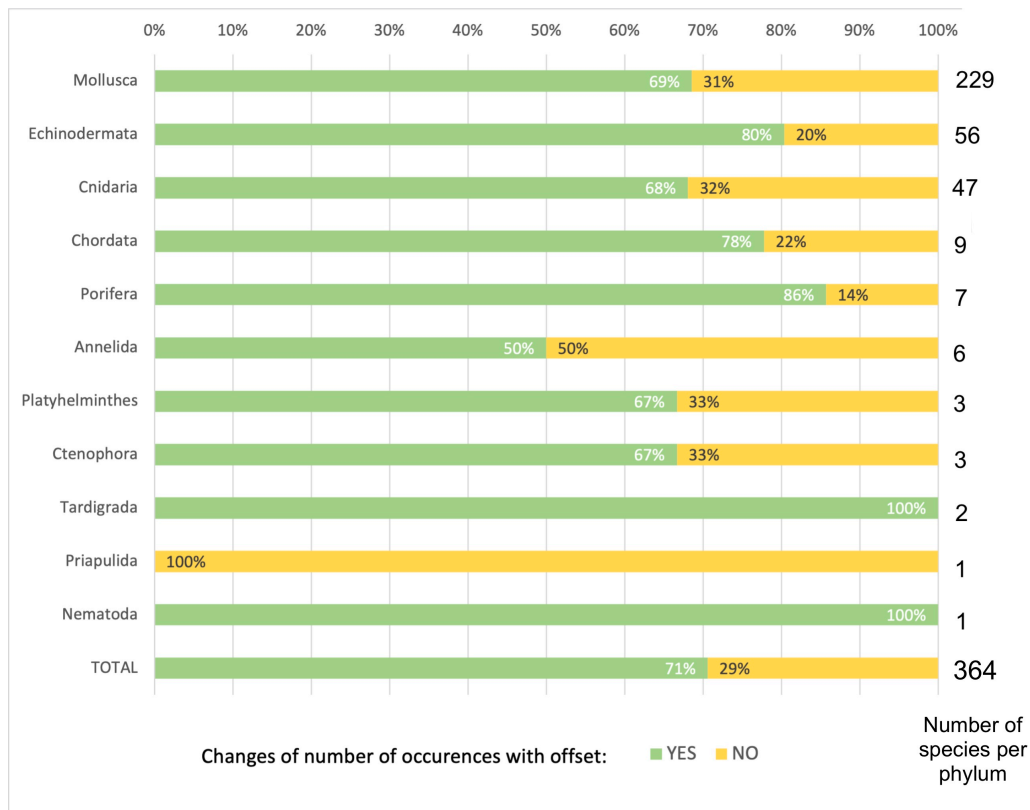
Observing the CA of all the species (Fig. 7b) allowed to see which species were responsible for the different patterns. In summary, this analysis gives a broad image of changes in species' composition and occurrence record density, per "period · zone". It proved that in each zone, the species composition of invertebrates has changes in the last 150 plus years.



**Figure 7:** Correspondence Analysis plot of invertebrate occurrence records in the Barents Sea from before 1900 to 2010. Ordination shown by a) the “period · zone” mean distribution, b) species associated with the data period · zone patterns, c) combination of a) and b) with PC1, PC2 and eigenvalues (species names are numbered). pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Zones are shown in Figure 4b. Periods are shown in Figure 5b.

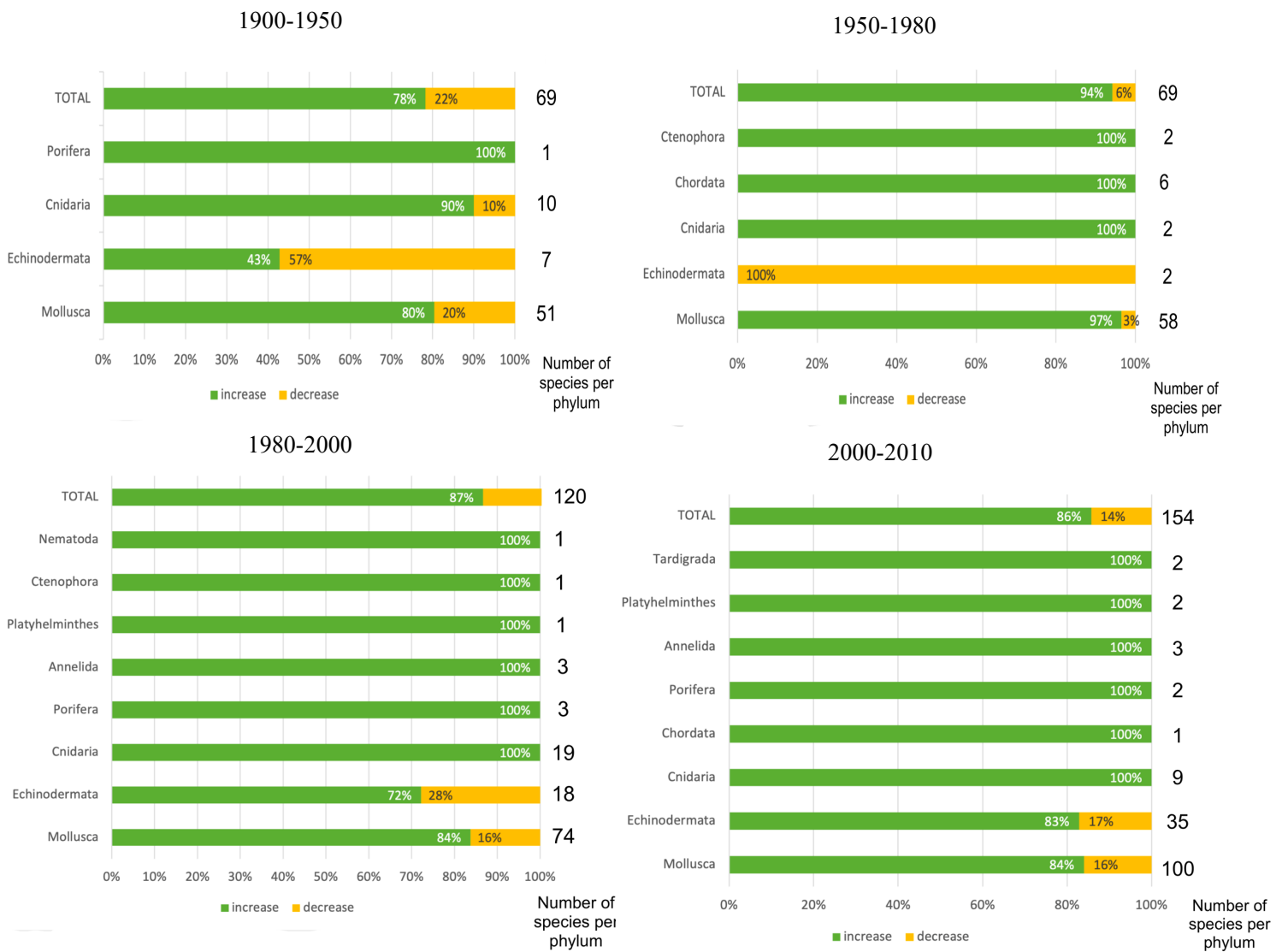
## 4.2 Log-linear models: difference of number of occurrences

The Log-linear models tests were done species by species individually and offer a result detailed to the species level (Appendix Table log linear models results). The dataset contained 364 species representing eleven phyla. All phyla but one showed significant differences of observation record density among time frames (Fig. 8). However, it is important to keep in mind that only three phyla have more than ten species in our dataset, molluscs, echinoderms, and cnidarians. Those three phyla are composed of most species with a significant difference of corrected occurrences (i.e., with an offset applied) between before 1900 and any other periods according to the log linear model. The proportion of species with a significant shift in occurrences were 69% of molluscs, 80% of echinoderms and 68% of cnidarians (Fig. 8).



**Figure 8:** Significant change of occurrence record density in invertebrate species per phylum from before 1900 until 2010 in the Barents Sea (indicated in green). “YES” means species showed a significant change in occurrence in at least one period relative to the reference period; “NO” means that in none of the period were there a significant change of occurrences. % values indicate the proportion of taxa in each phylum for which a statistically significant change was found.

Looking into the direction of the change per period, it is interesting to note that most of the species increase in observation density in every period (Fig. 9). The exceptions are echinoderms that significantly decrease in occurrence number from between 1900 to 1980 in comparison to before 1900. Of all mollusc species, for all periods combined, 86% present a significant increase in occurrence number, and the significant increase was by 73% for echinoderms and 98% for cnidarians.



**Figure 9:** Direction of change of observation density of invertebrates over time per phylum from a given period compared to before 1900 in the Barents Sea.

In our dataset we observe that more species appeared with each period. After 1900, 48 species emerged, i.e., 13% of the total amount of species found in the Barents Sea during the observation period, including 22 molluscs. After 1950, 49 more species appeared relative to the preceding period, mostly molluscs once again. After 1980, 64 species or 18% of the total amount of species found during that period in the Barents Sea, appeared, including 26 molluscs, 18 cnidarians and 12 echinoderms.

After 2000, 60 species that were previously unrecorded emerged, which makes up 16% of the total number of species. Most of those 60 species were molluscs and echinoderms, notably *Ophiecten affinis*, which has over 1000 observations after 2000 but inferior to 10 occurrences in a given period and region prior to 2000.

Some species also disappeared from our dataset after each period. All species present before 1900 did appear in at least one subsequent time period, although a few only appeared almost a decade after their first occurrence, such as *Thracia devexa* and *Erginus rubellus*. Only four species disappeared past 1950, notably *Stegophiura nodosa* that had 169 and 269 observations before 1900 and in 1900-1950, respectively. Past 1980, two species disappear from our dataset, *Boreochiton ruber* and *Neptunea antiqua*. All species consistently present prior to 2000 were also found in 2010.

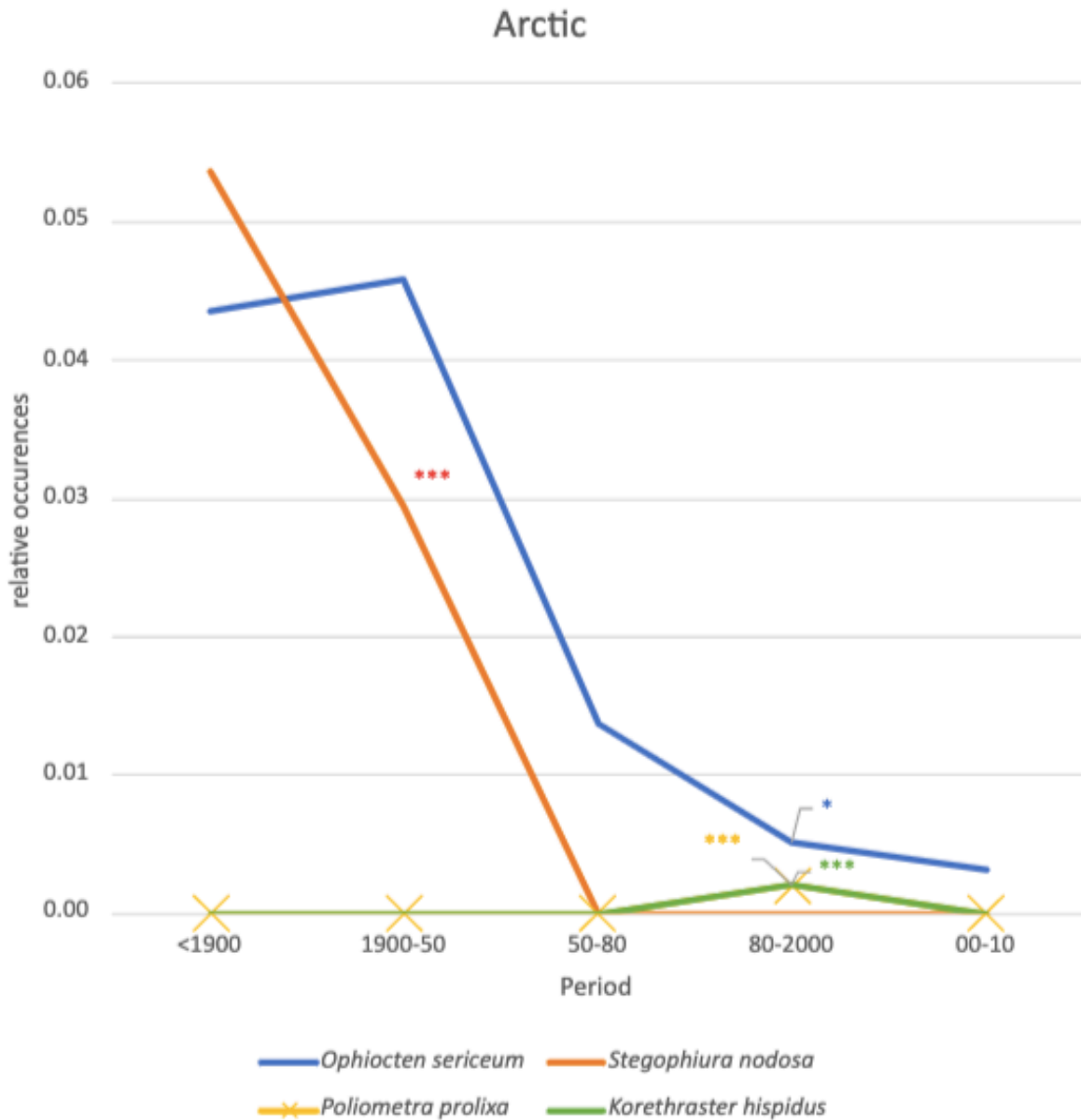
### 4.3 The Importance of an offset

The comparative histograms (Appendix Comparative figures showing occurrences changes calculated with and without offset) show how considering the pressure of observation, or observation effort, in the analysis can change the interpretation of the log-linear model results. For example, the number of occurrences of *Pteraster militaris*, an echinoderm, significantly increased ( $p < 0.1$ ) from before 1900 to 1900-1950 based on the log-linear model without the offset. However, the total amount of observation in those periods is not equal. Hence the offset takes the sampling effort into account. Using the offset, the number of occurrences of *Pteraster militaris* decrease significantly from before 1900 to 1900-1950 with a  $p < 0.05$ . Not all species showed a different result with offset compared to without, but out of 364 species tested 46 or 18% presented a different result.

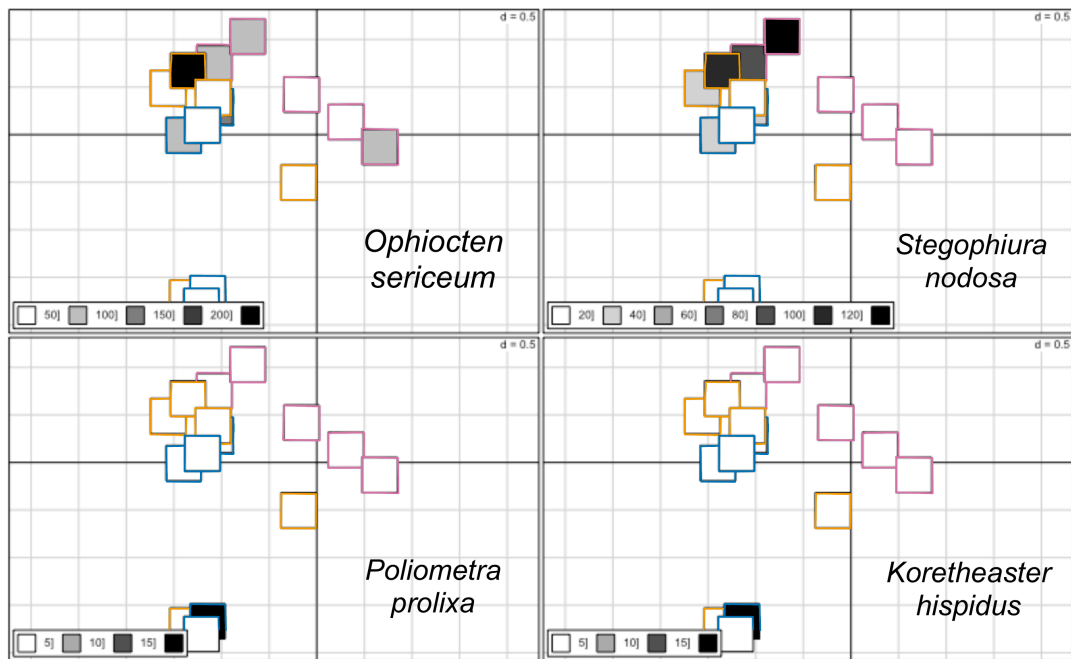
### 4.4 Shift in species occurrence patterns

#### 4.4.1 Species that have decreased in occurrences or shifted spatially

Out of the taxa whose occurrence records declined, echinoderms had the highest proportion of decline of all phyla in each period (Figure 9). Two Arctic echinoderms are given as examples. *Stegophiura nodosa* and *Ophiocten sericeum* are ophiuroids and showed significant decrease ( $p < 0.001$ ) in observation density in 1900-1950 compared to before 1900 for *S. nodosa* and in 1980-2000 for *O. sericeum* ( $p < 0.05$ ) (Fig. 10). Both were present in all three zones, with differing occurrence record patterns. *S. nodosa* had most observations before 1900 in the warm zone and between 1900-1950 in the warm and mixed zones whilst *O. sericeum* was the most observed in 1900-1950 in the cold zone (Fig. 11).

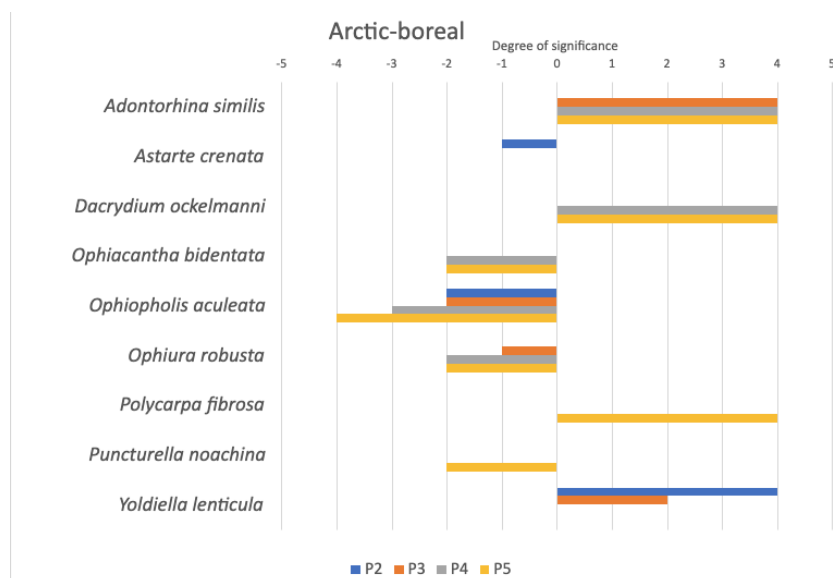


**Figure 10:** Number of corrected observations (i.e. offset applied) of four Arctic echinoderm species from before 1900 to 2010 in the Barents Sea. Y-axis: relative occurrence, X-axis: time periods. *Ophiecten sericeum*: "\*"  $p < 0.05$ , decreasing of the observation in 1980-2000; *Stegophiura nodosa*: "\*\*\*\*"  $p < 0.001$ , decreased of occurrences in 1900-1950; *Poliometra prolixa* and *Korethraster hispidus* (superimposed) "\*\*\*\*"  $p < 0.001$ , increased in the observation in 1980-2000. All changes are relative to before 1900.

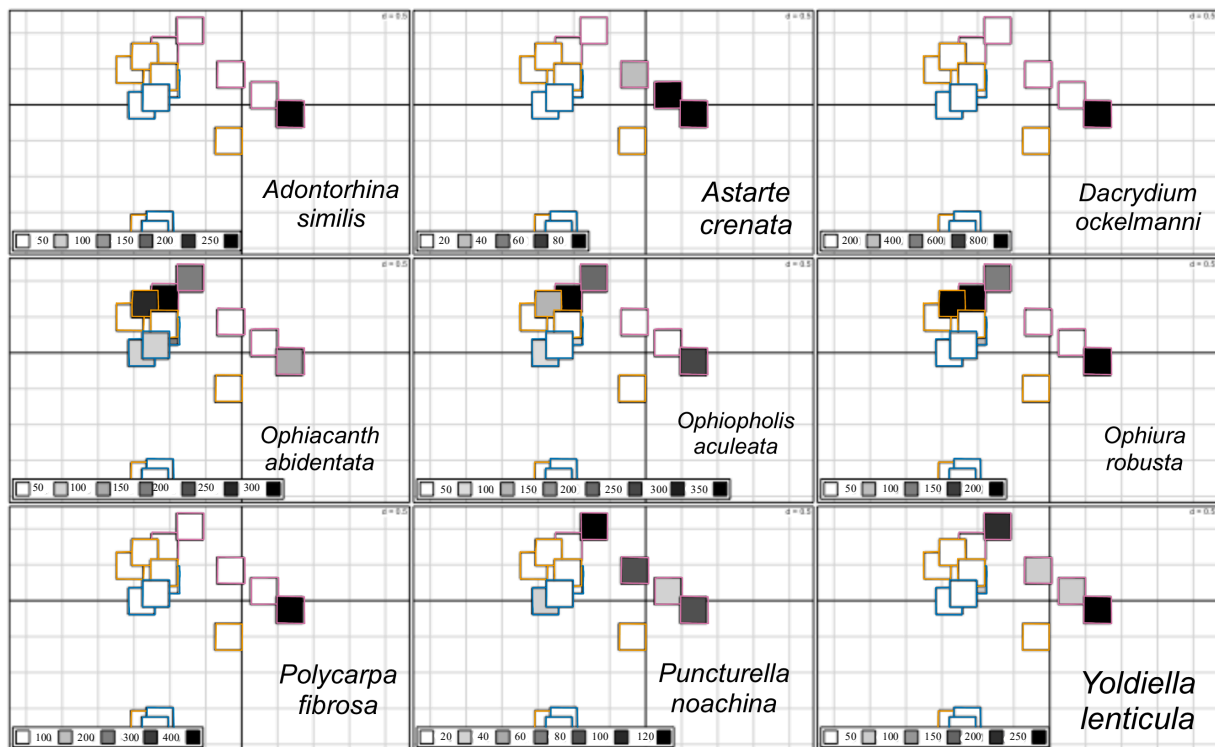


**Figure 11:** Zone · period specific abundances of four Arctic species, from the CA in Figure 6a. Colour of each box corresponds to the time per zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Amount of occurrence is given by the grey shading, with different scales for each panel. In *P. prolixa* and *K. hispidus*, occurrence numbers increased drastically in the mixed zone in 2000-2010. In *O. sericeum* and *S. nodosum* occurrence numbers dropped towards 2000-2010 in the cold and mixed zones (and in the warm zone for *S. nodosa*).

In addition, the following Arctic-boreal species showed a significant decrease in occurrence records, *Astarte crenata*, *Ophiacantha bidentata*, *Ophiopholis aculeata*, *Ophiura robusta* and *Puncturella noachina* (Fig. 12). All but *A. crenata*, could be found in the mixed and warm zone, whereas *A. crenata* could only be found in the warm area (Fig. 13).



**Figure 12:** Degree of significance relating to the changes in number of corrected (i.e. offset applied to log-linear models) observations of Arctic-boreal species relative to before 1900 (P1, reference to P2 and hence not shown) to 2010 in the Barents Sea. Below 0: decrease of observation density, above 0 increase of observation density. Degree of significance “1”  $p < 0.1$ , “2”  $p < 0.05$ , “3”  $p < 0.01$ , “4”  $p < 0.001$ . P2 is 1900-1950, P3 is 1950-1980, P4 is 1980-2000, P5 is 2000-2010.



**Figure 13:** Correspondence analysis showing occurrence records of nine Arctic-boreal species over time. The colour of each box corresponds to the time frame by zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Gray shades show the bins of offset-corrected occurrence records. In most cases the number of occurrences increased in 2000-2010 (furthest right square) in the warm zone.

#### 4.4.2 Species that have increased in occurrences or shifted spatially

Examples of Arctic species that significantly increased in occurrence records and shifted spatially are sea-star *Korethraster hispidus* and the Arctic crinoid *Poliometra prolixa* which showed a significant increase ( $p < 0.001$ ) in occurrence records in 1980-2000 compared to before 1900 (Fig. 10). Geographically both *K. hispidus* and *P. prolixa* were mostly present in the mixed zone, between 1980-2000 (Fig. 11).

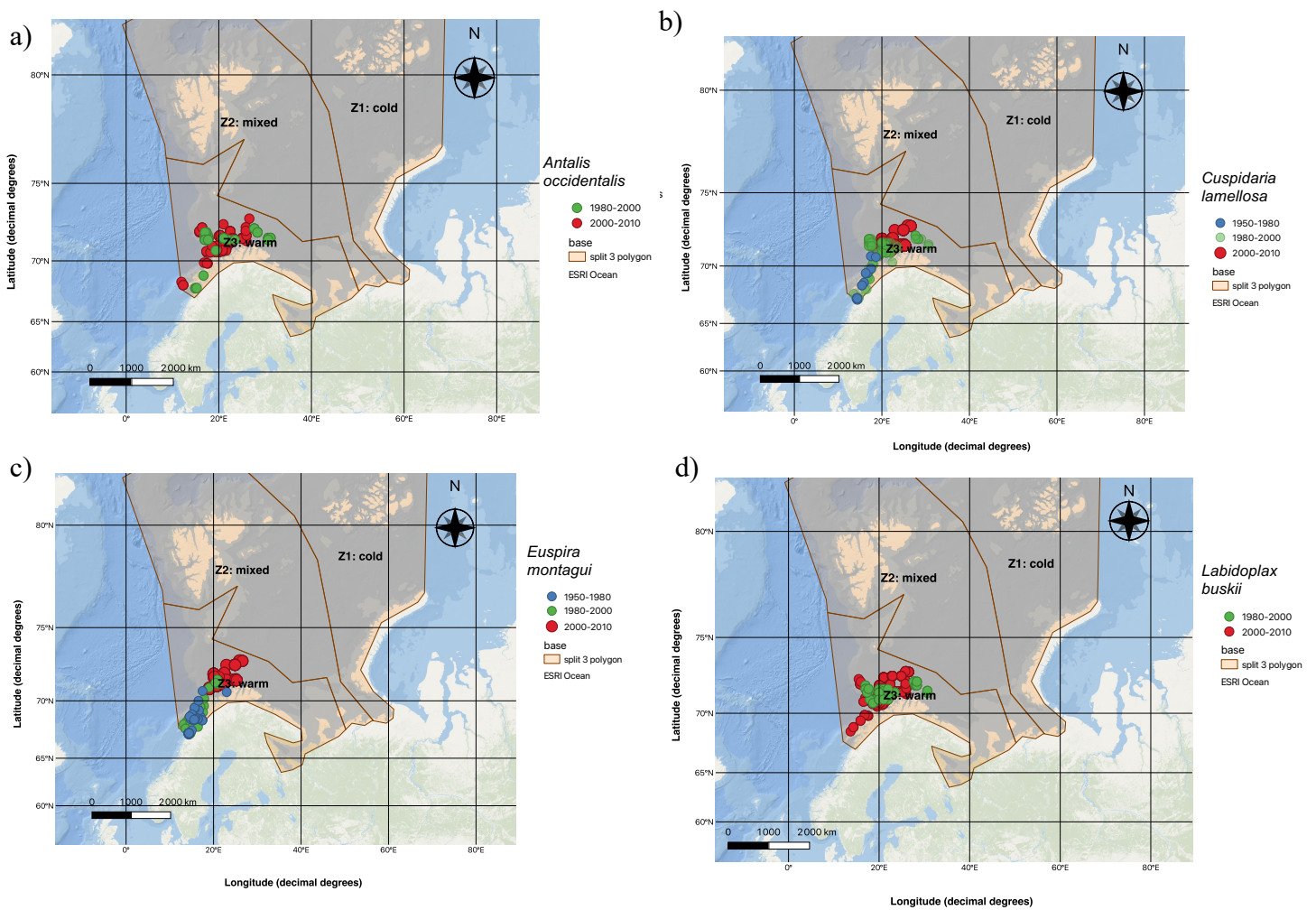
Over the last century, four boreal species significantly increased in occurrence records, three are molluscs, *Antalis occidentalis*, *Cuspidaria lamellosa* and *Euspira montagui* and *Labidoplax buskii* is an echinoderm. *A. occidentalis* is a boreal scaphopod, found mostly in 2000-2010 in the warm zone (Fig. 15). In both 1980-2000 and 2000-2010, the species showed a significant increase ( $p < 0.001$ ) in the number of observations. Looking at the observations on a map of the Barents Sea, the geographic distribution stayed relatively similar (Fig. 14).

*L. buskii* is a boreal sea cucumber (Holothuroidea) mostly present in 1980-2000 and 2000-2010 in the warm area (Fig. 15). Both time frames present an increase in the number of occurrences ( $p < 0.001$ ). On a map of the Barents Sea the geographic distribution of the species also stayed relatively the same from one period to another (Fig. 14).

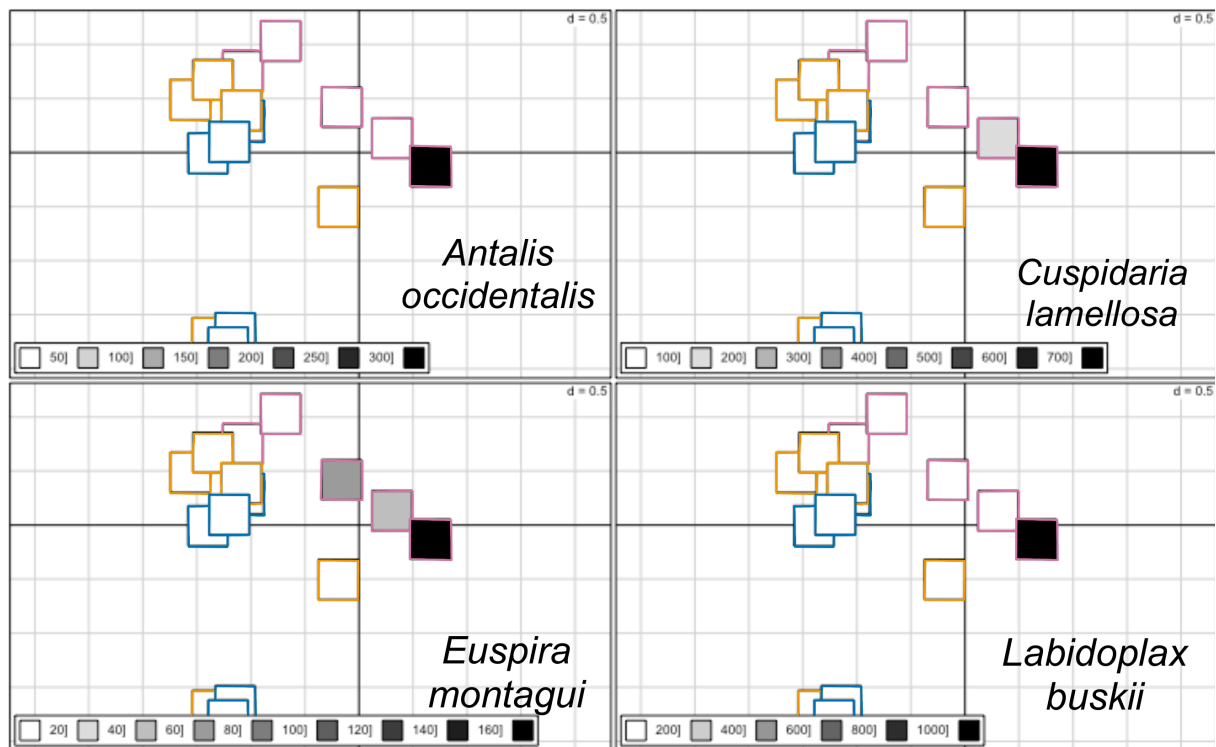
*C. lamellosa* is a boreal bivalve. Occurrences were mostly found during 2000-2010 in the warm zone (Fig. 15). The periods of 1950-1980, 1980-2000, and 2000-2010 all present

significant increase in number of observations ( $p < 0.001$ ). On a map of the Barents Sea the distribution seems to have moved northwards with time (Fig. 14).

*E. montagui* is a boreal gastropod. Most of the observations were in 1950-1980, 1980-2000, and 2000-2010 in the warm region (Fig. 15). Those three periods present a significant increase in number of occurrences ( $p < 0.001$ ) as well. On a map of the Barents Sea the distribution of *E. montagui* appear to be moving northwards with time in a similar manner as *C. lamellosa* (Fig. 14).



**Figure 14:** Map of the distribution of Arctic species in the Barents Sea a) *Antalis occidentalis*, b) *Cuspidaria lamellosa*, c) *Euspira montagui*, d) *Labidoplax buskii*. Blue dot: 1950-1980, green: 1980-2000, red: 2000-2010. Orange polygons represent the study zone and the three zones.



**Figure 1511:** Correspondance analysis of invertebrates in zone · periods in the Barents Sea with occurrence record density of four boreal species shown, colour of each box corresponds to the time per zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Occurrence densities increased in all cases in the warm zone with time, especially in the 00-10 period (furthest right square).

## 5 Discussion

### 5.1 Critical reflection on our method

#### 5.1.1 Bias present in our data

##### 5.1.1.1 Bias created before publication.

Our data is composed of thousands of observations made over nearly two centuries. When working on a data period as broad as centuries we find changes in the methodology used from one decade to another (Lenoir et al., 2020; Wessels et al., 2014). Through the centuries, improvements were made in the mechanics and gear used on boats (Nekhaev, 2014) such as grabs, trawls and plankton nets (Nekhaev, 2014). Trawls can be traced back to the late 14<sup>th</sup> century (Roberts, 2002) although in the 19<sup>th</sup> century their application has become more common in oceanography (Dunn, 2021). Other common tools are grabs, one of the first grab to be invented was the Van Veen grab sampler in 1933 (Van Veen, 1936). Gears each have their advantages and disadvantages and introduce a possibility of under-collecting or over-collecting a species, for example based on their mesh or sieve size used in the field (Nekhaev, 2014). Today a diversity of benthic grabs and trawls exists for scientists to buy and equip their boat, each with various sizes and approaches for work with different sediment, environment, and species. However, this diversity of choice can create difference in the manner data is created and shared (Yu et al., 2022).

Different types of data collected and the different biological disciplines, contributes to an uneven development of open access data (Wessels et al., 2014), as researchers are working with different aims. There is a variation in the sampling effort in space and time amongst datasets (Yu et al., 2022). According to Lenoir et al. (2020), for instance, this difference in methods from scientist to scientist has its consequence in the observed variation in the velocity of movement of species' distribution (Lenoir et al., 2020). An additional bias can be caused by the individuality of researchers. This, and the increase of our knowledge in taxonomy, has created a bias concerning whether a species was present before but overlooked, or is new to the area (Nekhaev, 2016; Nekhaev & Krol, 2017).

Regarding representation of taxa the most species rich phylum in invertebrates is arthropods and secondly molluscs ([WoRMS](#)). However, in our dataset arthropods are excluded. Although they are present in GBIF, a coding error occurred during the process and was discovered too late to be fixed for this thesis. Unequal representation of taxa could also, in part, be due to the comparatively easy identification of shelled mollusc. Shelled molluscs have an advantage as they can be identified after the death of the animal (Nekhaev & Krol, 2017).

Another source of bias in our study is the possibility of mis-identifying a specimen. Studies such as the one conducted by Nekhaev and Merkuliev (2021) found that the identification of marine species is far from perfect, many misidentification can be present in older and recent checklists of species (Nekhaev & Merkuliev, 2021). There is a lack of taxonomists in the scientific community today, especially for small species (Rocha-Ortega et al., 2021). In the last 50 years the number of taxonomists and their financial resources have dropped significantly (Kim, 1993). The work of a taxonomist can be tedious, detail-oriented and requires a long time and specific knowledge of the diversity of a group of species.

It is known that invertebrate conservation is not a priority over their vertebrate counterparts (Leather, 2013). Invertebrates are often under-collected and overlooked (Rocha-Ortega et al., 2021). Most invertebrates are not as intensely studied as other animal species such as mammals or certain fishes that have higher commercial value and are much more charismatic and cared about by the public (Lenoir et al., 2020). Although some invertebrates with a commercial value, such as certain crustaceans, Pectinidae, or *Mytilus edulis* (blue mussel), are well studied ex situ and in situ in harvesting areas (Aschan & Ingvaldsen, 2009). Interest of the public and commercial actors influence governmental attention and make the task of spreading knowledge about a species easier (Lenoir et al., 2020).

The consequence of these variables: gear, methods, scientific discipline, and taxonomy can have contributed to the appearance of previously unrecorded species in each period considered here. There is a possibility that these newly appeared species were previously overlooked. Perhaps, species that disappear from our dataset are more likely to no longer be found in the study area, though incomplete data archival in GBIF may also be a cause.

#### **5.1.1.2 Bias present in open-source data**

Online data availability for the whole scientific community is a key criterion to facilitate scientific cooperation and research progress. However, it comes with a certain number of issues that could lead to bias in a study using open access online data. An important bias is the constant evolution of taxonomy. Taxonomic names are updated, groups are split or fused, position on the taxonomy tree changed which can make work on past species occurrences data

harder (Høisæter, 2009). Organizations such as GBIF usually take these updates into account. Updates on digital platforms are more feasible to implement as opposed to printed checklists, which can only be updated and revoked. However, older printed version can still be found and confused for the latest version.

Integrative bioinformation and open database tools allow for a rapid estimate of large-scale patterns of biodiversity across space. However, geographic inaccuracy found in occurrence mapping may affect diversity displays more than taxonomic ambiguities (Maldonado et al., 2015). This bias can often lead to false positives, in other words, an overestimation of species richness relatively to regions poorer in species (Maldonado et al., 2015). For example, arthropods worldwide suffer from a highly biased sampling effort. On GBIF, arthropods are geographically underrepresented, and less than 3% of the arthropod data categorized by the International Union for Conservation of Nature were georeferenced (Rocha-Ortega et al., 2021). Georeferenced data was necessary for this study. Another spatial bias is introduced as not all continents are sampled equally. The development of open access policies and enforcement is also unequal across the diverse stakeholder groups (Wessels et al., 2014). In the last 40 years combined (1981-2020), more samples were taken than in the past century demonstrating an inequality of sampling throughout history as well as geographically (Rocha-Ortega et al., 2021).

A major concern with data quality is the need to apply more taxonomic knowledge, time and finances into verifying and cleaning the data present in public databases, such as GBIF and WoRMS for example. As of now leaving feedback on specific records, correction misidentification, false georeferencing, is not an straightforward task (Maldonado et al., 2015).

On GBIF, the bias is not only due to uneven effort of sampling as mentioned earlier but also to data storage and mobilization capacities. These issues are not native to GBIF but are very pronounced due to the nature of the data of GBIF. Data provided to GBIF by individual researchers and groups reflect differences in funding available to quality assessment and control which ultimately the data quality of the data providers' contribution to GBIF (Beck et al., 2014). Although GBIF is not the only initiative of its kind, it is by far the largest and is therefore seen as a major step in the closing of data gaps (Beck et al., 2012; Jetz et al., 2012). While quality issues in GBIF's data and the lack of transparency of data quality have been noted by many and were also publicly criticised (Graham et al., 2008; Soberón et al., 2002; Yesson et al., 2007) it is without doubt that biodiversity data availability has advanced greatly since the advent of online data bases such as GBIF.

### **5.1.2 Solution to counter the biases**

To counter temporal and spatial biases present in the datasets I downloaded from GBIF, I used diverse methods. First, the period of the data of the study stops at 2010. While 2010 was a somewhat arbitrary cut-off, it was a choice to not include more recent years as the chosen approach gives us better odds of having the best available data coverage until 2010 included, while the specimens caught in an expedition conducted in, for example, 2022 might still not be identified or processed yet. The true distribution of organisms in 2010-2022 is therefore likely not complete yet.

Second, I used additional resources to verify the distribution of the species selected and to remove likely artefacts found to obtain the most robust dataset. However, there is still the possibility of hidden artefacts in our datasets. GBIF also has a quality control built in, which compares coordinates with the country referenced in the metadata and flags possible mismatches.

Lastly, the use of an offset in the log-linear models allowed to take the unequal observation effort across time into consideration directly in the calculation. It is my opinion that including the offset is critical as it was clear that research effort across the study region was unequally distributed. The fact that 18% of all taxa presented a different result when applying the offset indicates that my conclusions would probably have been incorrect for around a fifth of all species had I not applied the offset.

Another idea to counteract bias present in open-source data is to allow users to review datasets and leave feedback on their accuracy and correct errors as suggested by Maldonado et al. (2015). Such initiatives that engage the broad public have emerged and also enhance the reporting of identified species on earth, such are [idigbio.org](http://idigbio.org), [ispotnature.org](http://ispotnature.org) or [inaturalist.org](http://inaturalist.org). Rapid change is needed in the way taxon observations are reported to push forward our knowledge on biodiversity and distribution pattern in a time of rapid biodiversity change (Maldonado et al., 2015).

## **5.2 Changing distributions of marine invertebrates in the Barents Sea**

### **5.2.1 Temporal patterns**

#### Before 1900, 1900-1950:

Before 1900, each zone of the Barents Sea had a different species composition. In 1900-1950 increasing numbers of occurrence and emergence of species previously undetected in the area were found, yet changes seen in the Correspondence Analysis were moderate relative to later periods. Most increases were likely in part due to the increase in taxonomic knowledge and in the types of tools used during expeditions. The distribution in the north and the centre of the Barents Sea continued to be relatively similar between the 1900 and 1950. However, the occurrences distribution in the Southern Barents Sea started to shift from this time on. The temperature of the Barents Sea in the first half of the 20<sup>th</sup> century oscillated, with a cold period in 1925, and warmer one in 1950 (Levitus et al., 2009). This oscillation is reflected in our data, with the species composition moving upward in the CA for all zone in 1900-1950 relative to before 1900.

#### 1950-1980:

Between 1950 and 1980, the three geographic zones presented different patterns of invertebrate occurrences. Specifically, the warm zone in the south-west of the Barents Sea had its species composition change steadily throughout the data periods considered. Meanwhile the cold and mixed zone stayed relatively similar to their previous period and to each other. Coincidentally, the northern North Atlantic Ocean experienced a significant temperature increase between the 1920s and 1960s, resulting in warmer water, decreased sea-ice, and changes in migration patterns of fish species (Drinkwater, 2006). Warmer-water fish species migrated further north while colder-water species retreated even further north in the

Barents Sea. This event led to the appearance of new species and changes in spawning sites (Drinkwater, 2006). These warmings in questions could have led the succinct shift in invertebrates observed and described after 1980 as well.

#### 1980-2000:

The biggest shift of distribution of invertebrates in the Barents Sea compared to before 1900, inferred from changes in occurrence patterns, happened after 1980. Occurrences of certain Arctic species, e.g., *Ophiecten sericeum*, decreased significantly in amount during this period. Occurrences of other species, Arctic-boreal and boreal alike increased, e.g., *Euspira montagui* and *Cuspidaria lamellosa*. This change in occurrences indicates a shift of distribution northwards that most likely can be attributed to the warming of the waters during that period. Additionally, a second warm period started in the 1990s and continues to the present day, covering northern regions above 60° and extending to 30°N in its southern extent (Drinkwater, 2009). During the previous warm period, cod stocks in various regions, including West Greenland and the Barents Sea, thrived, showing increased abundance, growth, recruitment, and northward migration. Bottom-up processes, indicated by plankton data, were responsible for these changes in cod behaviour (Drinkwater, 2009). Additionally, between 1994 and 1996, a change in the benthic community was observed, coinciding with a shift of the North Atlantic Oscillation Index from positive to negative mode. During this period and subsequent years, biodiversity increased, certain taxa such as actinarians declined, and dense carpets of brown algae appeared at Svalbard coastal sites (Beuchel et al., 2006). Extended macroalgal cover, related to sea ice decline along Svalbard coasts, facilitated additional species to settle (Kortsch et al., 2012). Again, any change in the taxon composition also affects food web links of all species involved.

#### 2000-2010:

Past the 2000s, all three zones presented divergent species occurrence patterns, even the previously similar cold and mixed zones are now clearly separated in the CA. Arctic species decreased further in number e.g., *Stegophiura nodosa* and *Ophiecten sericeum*, certain boreal species increased further, e.g., *Cuspidaria lamellosa* and *Euspira montagui*. However, no species observed before 2000 disappeared from our dataset afterward.

The observed changes in occurrence records are consistent with oceanographic changes. In the mid-2000s, a rapid climate shift took place in the Barents Sea (Lind et al., 2018). Multiple points led to this: A warmer surface layer and less stratification of the water column due to declining freshwater input from reduced ice melt increased vertical mixing such that warming waters increasingly extended to the seafloor (Lind et al., 2018). Boreal species are further increasing in number and extending further north and north-eastward and Arctic species are decreasing and their spatial range is reduced to the northeast (Zakharov et al., 2020). The macrobenthic community in an Arctic fjord (Kongsfjorden, Svalbard) in Norway has seen their structure shift between 1994 and 1996. Dates overlap with a major change from positive to negative in the North Atlantic Oscillation Index (NAOI) regime (Beuchel et al., 2006).

## **5.2.2 Spatial patterns – Borealization**

About 10 000-year B.P. a major faunal shift happened in the Barents Sea, Arctic fauna was replaced by boreal fauna and then shifted into the modern fauna. The main factor was most likely increased temperature, salinity and nutrients, all brought by the North Atlantic Current

(Thomsen & Vorren, 1986). We can expect a major faunal shift to the entire Barents Sea ecosystem in the future (Frainer et al., 2017).

Overall, all phyla considered in this study were affected by Borealization. Borealization is a phenomenon where sub-Arctic Atlantic and Pacific waters and their biota are brought into the polar region (Polyakov et al., 2020) (Polyakov et al., 2020). As previously mentioned, climate directly correlates with distribution of species in the Barents Sea (Hastings et al., 2020; Nascimento et al., 2023).

The Arctic is anticipated to have the biggest turnover in invading and locally extinct species, the invasion intensity was modelled to be five times stronger than the global average (Cheung et al., 2009). The highest rates of change can be expected in the northern most points as the increase of temperature is strongest there (Timmermans et al., 2015).

Borealization is visible on many scales, such as the fish communities (Cheung et al., 2009). Boreal fish communities are expanding north, with a velocity mirroring local climate shift, and Arctic fish community is retracting even northward (Fossheim et al., 2015). The Arctic fish community was mostly small bottom-dwelling benthivores, whilst the incoming boreal species have different traits, larger, longer lived and piscivorous species (Frainer et al., 2017).

A major characteristic of those boreal fishes is high generalism, which allows them to increase their connection with species of the Arctic marine food web and reduce their modularity, in other terms, reduce their connections with their communities (Kortsch et al., 2015). An example of expansion of boreal fishes into the Arctic is the mackerel (*Scomber scombrus*), found in Isfjorden, Svalbard, in 2013. This point hold the record of the most northern observation of mackerel (Berge et al., 2015).

The shift in fish community is expected to have repercussions in other faunal components, such as the benthos and zooplankton (Dalpadado et al., 2020). Changes of occurrence in species higher in the food chain will affect species lower, such as invertebrates. However, these groups are also affected by Borealization in their own way. While food webs are intrinsically linked together each group can also be investigated individually.

Between 1998 and 2017, the net primary production rate of the Barents Sea has more than doubled (Dalpadado et al., 2020). Due to the reduction of sea ice, the temporality and location of phytoplankton production has extended. The peak period of the phytoplankton bloom has advanced by over a month as well as extended in time. Reduction of sea-ice and simultaneously sea-ice algae is likely to negatively impact ice dependent species and the sympagic fauna (Dalpadado et al., 2020).

In my dataset the bivalve *Cuspidaria lamellosa* and the gastropod *Euspira montagui* showed clear signs of Borealization. *Cuspidaria lamellosa* is a burrowing predator (Pearson et al., 1996; Thomsen & Vorren, 1986). On GBIF before 1980 less than 20 observations are registered in the world's oceans. The majority is registered past 2000, and virtually all were found along the coast of Norway. In 1996, 301 specimens were observed in the Northern North Sea (Pearson et al., 1996). Some were also present as fossil 10 000 years B.P. along Senja island, Norway (Thomsen & Vorren, 1986). To now find them in the Southern Barents Sea show a movement of the species northward. In addition, my rendition of their observation on a map, shows a steady directional move north starting in 1950 (Fig. 14).

*Euspira montagui* is a carnivorous gastropod (Durieux et al., 2010). The usual distribution of *E. montagui* is in the Northeast Atlantic: from Iceland to UK, East of Baltic Sea and north to Norway. Embryos develop into planktonic trochophore larvae and later into juvenile veliger before becoming fully grown adults ([WoRMS](#)). According to my findings, they are now present in the Southern Barents Sea and moving northward from 1950 to 2010 (Fig. 14). Both *C. lamellosa* and *E. montagui* present signs of Borealization.

Other common species in the dataset were *Antalis occidentalis* and *Labidoplax buskii*. The tusk shell *A. occidentalis* has an internal fertilization with the eggs hatching as free-swimming lecithotrophic trochophore larvae, which will then turn into shelled veligers (Steiner & Kabat, 2004). They are therefore planktonic as eggs and larvae and then mostly sessile as adult. *A. occidentalis* is mainly found along the East coast of North America and the Norwegian coast. Using the GBIF occurrence map, 0 observations are shared along the coast of Norway until 1950, between 1950-1990 a few can be seen, however most of the occurrences on GBIF for this species were observed past 2000 along the Norwegian Coast. Other checklists of species note single observations of this species on the Norwegian coast in 1859 (Steiner & Kabat, 2004). Due to the sporadic upload of observations on GBIF we cannot make a clear statement regarding changes in distribution for this species.

*L. buskii* has an exterior spawning and fertilization, the embryos develop into planktonic larvae and eventually become sea cucumbers (Coll et al., 2010). Using the species description of WoRMS, the distribution of the sea cucumber *L. buskii* is in the Irish Sea, Clyde and North Sea, and the GBIF mapping data tool also shows the entire coast of Norway as the distribution range. In 1969, *L. buskii* was found in the Mediterranean Sea, in Banyuls-sur-Mer (Cherbonnier, 1969). Another first-time observation, far from their usual distribution pattern, were made in Canada, in 2009 (Massin et al., 2014). Banyuls-sur-Mer and Nova Scotia respectively range between 9 to 23°C in 1967 (Jacques et al., 1969) and 2 and 12°C in 2009 (Scheibling et al., 2013). Due to this finding, we can observe how *L. buskii* started as a warm species and is now found much further north across the Atlantic. We can interpret this change of distribution as Borealization. However, *L. buskii* is described as small and transparent (30mm) and is supposedly potentially often overlooked (Ursin, 1960).

My observations of Borealization is consistent with published findings. Additional examples of Borealization are the two *Gammarus* species, *G. setosus* and *G. oceanicus*. *G. setosus* is an arctic amphipod and *G. oceanicus* is a boreal species, they were investigated in the Spitsbergen littoral, in Svalbard. The already local *G. setosus* did not present any shift of distribution. However, *G. oceanicus*, which previously was occasionally observed along the west and north coast of Spitsbergen, is now a dominating species. Consequently, this is an expansion of its distribution of over 1300km (Węśławski et al., 2018).

The phenomenon of Borealization is not just present in the Barents Sea, it can also be observed in the Pacific Arctic regions, namely the Bering Sea as well as the Chukchi Sea. In these regions Borealization is sometimes called Pacification where an increased influx of warmer Pacific waters increased the temperature as well as an expansion of Pacific species into the Arctic (Grebmeier et al., 2018; Polyakov et al., 2020). This Borealization in the Pacific inflow Arctic shelf could also be due to retreating sea-ice (Mueter & Litzow, 2008; von Biela et al., 2023).

## 6 Conclusion

This thesis aimed to explore potential shifts of distribution and number of invertebrates in the Barents Sea over a century using open-source data. My hypothesis was that due to warming waters in the Barents Sea, species more adapted for warm Atlantic water would increase over time. Investigating spatial patterns using a Correspondence Analysis, I established that the Barents Sea present different species communities depending on the area, North-east, middle and South-west. Additionally, these species communities shift their composition from before 1900 to increasingly divergent in 2010, with a strong turn after 1980. An implication of this is the possibility that as the warming increases the species communities have gotten further distinct from each other. Considering the increase in number of numerous boreal species, the evidence of this thesis suggests a Borealization of some species in the Barents Sea. This thesis demonstrates the utility of normalized open-access data from source such as GBIF.

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# Appendix

## Table of log linear model results

Table of invertebrate species from the Barents Sea sorted by phylum and class showing the log linear models results. Poisson and Quasi-Poisson, with and without offset for each period.

### Legend:

Significance codes:  $p < 0.001$ ;  $p < 0.01$ ;  $p < 0.05$ ;  $p < 0.1$ ; positive p value = increase; negative p value = decrease

P1: <1900; P2: 1900-1950; P3: 1950-1980; P4: 1980-2000; P5: 2000-2010

“TEST”: statistical test used to acquire the result.

“CHANGES?”: presence or absence of any significant changes in the amount of occurrences

“W/o”: log-linear models without the offset

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Abra longicallus</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes					0,001
<i>Abra nitida</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001	
<i>Abra prismatica</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes					0,001
<i>Acanthocardia echinata</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes					0,001
<i>Acanthotrochus mirabilis</i>	Echinodermata	Holothuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001	
<i>Aclis sarsi</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes					0,001
<i>Admete viridula</i>	Mollusca	Gastropoda	poisson	none					none					
<i>Adontorhina similis</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001	
<i>Aeginopsis laurentii</i>	Cnidaria	Hydrozoa	quasipoisson	none					none					
<i>Aeolidia papillosa</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001				
<i>Aglantha digitale</i>	Cnidaria	Hydrozoa	quasipoisson	none					none					
<i>Akera bullata</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001				
<i>Allantactis parasitica</i>	Cnidaria	Anthozoa	poisson	none					yes				0,05	
<i>Alvania cimicoides</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001			
<i>Alvania punctura</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001			
<i>Alvania subsoluta</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes					0,001
<i>Amauropsis islandica</i>	Mollusca	Gastropoda	poisson	none					none					
<i>Amphilepis norvegica</i>	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes					0,001
<i>Amphipholis squamata</i>	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001	
<i>Amphiura borealis</i>	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001	
<i>Amphiura filiformis</i>	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes					0,001
<i>Amphiura securigera</i>	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001		yes			0,001		
<i>Anatoma crispata</i>	Mollusca	Gastropoda	quasipoisson	none					none					
<i>Antalis agilis</i>	Mollusca	Scaphopoda	quasipoisson	yes			0,001	0,001	yes			0,001	0,001	
<i>Antalis entalis</i>	Mollusca	Scaphopoda	quasipoisson	none					none					
<i>Antalis occidentalis</i>	Mollusca	Scaphopoda	quasipoisson	yes			0,001	0,001	yes			0,001	0,001	
<i>Aplysilla sulfurea</i>	Porifera	Demospongiae	quasipoisson	yes				0,001	yes					0,001
<i>Aporrhais pespelecani</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001	0,001
<i>Arctica islandica</i>	Mollusca	Bivalvia	poisson	yes				0,01	yes	0,01		0,001	0,001	
<i>Ariadnaria borealis</i>	Mollusca	Gastropoda	poisson	none					none					
<i>Arianta arbustorum</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001				
<i>Arion fuscus</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001				

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Ascidia obliqua</i>	Chordata	Ascidacea	quasipoisson	yes		0,001				yes		0,001		
<i>Astarte crenata</i>	Mollusca	Bivalvia	quasipoisson	yes	-0,1					yes			0,05	0,05
<i>Astarte elliptica</i>	Mollusca	Bivalvia	quasipoisson	yes	-0,05		-0,05	-0,01		none				
<i>Astarte montagui</i>	Mollusca	Bivalvia	quasipoisson	yes	-0,1		-0,1	-0,05		none				
<i>Astarte sulcata</i>	Mollusca	Bivalvia	poisson	none						none				
<i>Asterias rubens</i>	Echinodermata	Asteroidea	quasipoisson	yes				0,001		yes				0,001
<i>Astyris rosacea</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Aulactinia stella</i>	Cnidaria	Anthozoa	quasipoisson	yes	0,001					yes	0,001			
<i>Aurelia aurita</i>	Cnidaria	Scyphozoa	quasipoisson	yes			0,001	0,001		yes			0,001	0,001
<i>Axinopsida orbiculata</i>	Mollusca	Bivalvia	poisson	yes	-0,01			-0,05		yes	-0,1			
<i>Axinulus croulinensis</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001		yes		0,001		0,001
<i>Bathyarca frielei</i>	Mollusca	Bivalvia	Quasipoisson	none						none				
<i>Bathyarca pectunculoides</i>	Mollusca	Bivalvia	poisson	none						none				
<i>Bathyrincus carpenterii</i>	Echinodermata	Crinoidea	quasipoisson	none						none				
<i>Bathymophalus contortus</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Bathypolypus arcticus</i>	Mollusca	Cephalopoda	quasipoisson	yes			0,001			yes			0,001	
<i>Beroe cucumis</i>	Ctenophora	Nuda	poisson	none						none				
<i>Bolinopsis infundibulum</i>	Ctenophora	Tentaculata	quasipoisson	yes		0,001				yes		0,001		
<i>Boltenia echinata</i>	Chordata	Ascidacea	quasipoisson	yes		0,001				yes		0,001		
<i>Boreacola maltzani</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001			yes			0,001	
<i>Boreochiton ruber</i>	Mollusca	Polyplacophora	poisson	yes	0,001	0,05				yes	0,001	0,001		
<i>Boreotrophon clathratus</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Boreotrophon clavatus</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001		yes				0,001
<i>Boreotrophon truncatus</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Botrylloides aureus</i>	Chordata	Ascidacea	poisson	none						none				
<i>Bougainvillia supercilialis</i>	Cnidaria	Hydrozoa	quasipoisson	yes			0,001	0,001		yes			0,001	0,001
<i>Brattegardia nansenii</i>	Porifera	Calcarea	quasipoisson	yes	0,001					yes	0,001			
<i>Brisaster fragilis</i>	Echinodermata	Echinoidea	quasipoisson	yes				0,001		yes				0,001
<i>Brissopsis lyrifera</i>	Echinodermata	Echinoidea	quasipoisson	yes				0,001		yes				0,001
<i>Buccinum cyaneum</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Buccinum finmarkianum</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001					yes	0,001			
<i>Cactosoma abyssorum</i>	Cnidaria	Anthozoa	quasipoisson	yes			0,001			yes			0,001	

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Cadulus jeffreysi</i>	Mollusca	Scaphopoda	quasipoisson	yes				0,001		yes				0,001
<i>Cadulus propinquus</i>	Mollusca	Scaphopoda	quasipoisson	yes				0,001		yes				0,001
<i>Cadulus subfusiformis</i>	Mollusca	Scaphopoda	quasipoisson	yes				0,001		yes				0,001
<i>Calliostoma occidentale</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001			-0,001		yes	0,001			-0,001
<i>Calycella syringa</i>	Cnidaria	Hydrozoa	quasipoisson	yes	0,001					yes	0,001			
<i>Campanularia volubilis</i>	Cnidaria	Hydrozoa	poisson	none						none				
<i>Capulus ungaricus</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001		0,001		yes		0,001		0,001
<i>Cardiomya cadiziana</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001		yes				0,001
<i>Ceramaster granularis</i>	Echinodermata	Asteroidea	quasipoisson	none						none				
<i>Cerastoderma edule</i>	Mollusca	Bivalvia	quasipoisson	yes	0,001	0,001				yes	0,001	0,001		
<i>Cerithiella metula</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Chaetoderma nitidulum</i>	Mollusca	Caudofoveata	quasipoisson	yes		0,001				yes		0,001		
<i>Chamelea striatula</i>	Mollusca	Bivalvia	quasipoisson	yes	0,001		0,001	0,001		yes	0,001		0,001	0,001
<i>Cladorhiza gelida</i>	Porifera	Demospongiae	quasipoisson	yes			0,001			yes			0,001	
<i>Clausilia bidentata</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001					yes	0,001			
<i>Cleandella mliaris</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Clione limacina</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Colus gracilis</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001		yes	0,001	0,001	0,001	0,001
<i>Coryphella verrucosa</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001					yes	0,001			
<i>Crenella decussata</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Crossaster papposus</i>	Echinodermata	Asteroidea	quasipoisson	yes	-0,01			-0,001		yes				-0,05
<i>Ctenodiscus crispatus</i>	Echinodermata	Asteroidea	quasipoisson	none						none				
<i>Curtitoma trevilliana</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Curtitoma violacea</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Cuspidaria lamellosa</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001		yes		0,001	0,001	0,001
<i>Cuspidaria obesa</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Cuspidaria subtorta</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Cyanea capillata</i>	Cnidaria	Scyphozoa	quasipoisson	yes			0,001	0,001		yes			0,001	0,001
<i>Cyclopecten hoskynsi</i>	Mollusca	Bivalvia	quasipoisson	none						yes				0,10
<i>Cylista splendens</i>	Cnidaria	Anthozoa	quasipoisson	yes			0,001			yes			0,001	
<i>Cyrellia aequalis</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Cyrellia linearis</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Dacrydium ockelmanni</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Dacrydium vitreum</i>	Mollusca	Bivalvia	quasi poisson	none					yes				0,05
<i>Delectopecten vitreus</i>	Mollusca	Bivalvia	quasi poisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
<i>Dendrodoa aggregata</i>	Chordata	Ascidiacea	quasi poisson	yes		0,001			yes		0,001		
<i>Dendrodoa grossularia</i>	Chordata	Ascidiacea	quasi poisson	yes		0,001			yes		0,001		
<i>Dendronotus frondosus</i>	Mollusca	Gastropoda	quasi poisson	none					none				
<i>Desmophyllum pertusum</i>	Cnidaria	Anthozoa	quasi poisson	yes	0,001				yes	0,001			
<i>Diaphana hiemalis</i>	Mollusca	Gastropoda	quasi poisson	yes				0,001	yes				0,001
<i>Didemnum albidum</i>	Chordata	Ascidiacea	quasi poisson	yes		0,001			yes		0,001		
<i>Dimophyes arctica</i>	Cnidaria	Hydrozoa	quasi poisson	yes	0,001				yes	0,001			
<i>Diplodonta torelli</i>	Mollusca	Bivalvia	poisson	none					none				
<i>Doto coronata</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001				yes	0,001			
<i>Echinocardium flavescens</i>	Echinodermata	Echinoidea	quasi poisson	yes				0,001	yes				0,001
<i>Echinocyamus pusillus</i>	Echinodermata	Echinoidea	quasi poisson	yes				0,001	yes				0,001
<i>Echinus esculentus</i>	Echinodermata	Echinoidea	quasi poisson	yes				0,001	yes				0,001
<i>Elpidia belyaevi</i>	Echinodermata	Holothuroidea	quasi poisson	yes			0,001		yes		0,001		
<i>Elpidia glacialis</i>	Echinodermata	Holothuroidea	quasi poisson	none					none				
<i>Emarginula crassa</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001			yes		0,001		
<i>Ennucula convexa</i>	Mollusca	Bivalvia	quasi poisson	yes				0,001	yes				0,001
<i>Ennucula corticata</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Ennucula tenuis</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Entalina tetragona</i>	Mollusca	Scaphopoda	quasi poisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Epizoanthus papillosus</i>	Cnidaria	Anthozoa	quasi poisson	none					none				
<i>Erginus rubellus</i>	Mollusca	Gastropoda	poisson	yes			-0,1		none				
<i>Euconulus fulvus</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001				yes	0,001			
<i>Eudendrium capillare</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001		yes			0,001	
<i>Eudendrium ramosum</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001		yes			0,001	
<i>Eulima bilineata</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Eulimella scillae</i>	Mollusca	Gastropoda	quasi poisson	yes				0,001	yes				0,001
<i>Eumetula arctica</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001			yes		0,001		
<i>Eupyrigus scaber</i>	Echinodermata	Holothuroidea	quasi poisson	yes			0,001		yes			0,001	
<i>Euspira montagui</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Euspira nitida</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001		0,001	yes		0,001		0,001
<i>Flabellum macandrewi</i>	Cnidaria	Anthozoa	quasi poisson	yes				0,001	yes				0,001
<i>Frigidaalvania janmayeni</i>	Mollusca	Gastropoda	quasi poisson	yes			0,001		yes		0,001		
<i>Galba truncatula</i>	Mollusca	Gastropoda	poisson	yes		-0,1			none				
<i>Genaxinus eumyrius</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Glandulactis spetsbergensis</i>	Cnidaria	Anthozoa	quasi poisson	yes			0,001		yes		0,001		
<i>Golfingia margaritacea</i>	Annelida		quasi poisson	none					none				
<i>Golfingia vulgaris</i>	Annelida		quasi poisson	none					none				
<i>Gorgonocephalus arcticus</i>	Echinodermata	Ophiuroidea	quasi poisson	yes	0,001				yes	0,001			
<i>Gorgonocephalus eucnemis</i>	Echinodermata	Ophiuroidea	quasi poisson	none					yes	0,05			
<i>Gracilechinus acutus</i>	Echinodermata	Echinoidea	quasi poisson	yes				0,001	yes				0,001
<i>Grammaria abietina</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001		yes		0,001		
<i>Gyrodactylus albolacustris</i>	Platyhelminthes	Monogenea	quasi poisson	yes				0,001	yes			0,001	
<i>Gyrodactylus arcuatus</i>	Platyhelminthes	Monogenea	quasi poisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Halcampa arctica</i>	Cnidaria	Anthozoa	poisson	none					none				
<i>Halecium beanii</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001		yes			0,001	
<i>Halecium labrasum</i>	Cnidaria	Hydrozoa	poisson	none					yes			0,05	
<i>Haliella stenostoma</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
<i>Halitholus yoldiae arcticae</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Halocynthia pyriformis</i>	Chordata	Ascidiacea	quasi poisson	none					none				
<i>Hanleya hanleyi</i>	Mollusca	Polyplacophora	quasi poisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
<i>Henricia perforata</i>	Echinodermata	Asteroidea	quasi poisson	yes				0,001	yes				0,001
<i>Henricia sanguinolenta</i>	Echinodermata	Asteroidea	quasi poisson	yes				0,001	yes				0,001
<i>Hermania scabra</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Heteranomia squamula</i>	Mollusca	Bivalvia	poisson	none					none				
<i>Hiatella rugosa</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Hippasteria phrygiana</i>	Echinodermata	Asteroidea	quasi poisson	none					none				
<i>Hormathia digitata</i>	Cnidaria	Anthozoa	quasi poisson	none					none				
<i>Hormathia nodosa</i>	Cnidaria	Anthozoa	poisson	none					none				
<i>Hydractinia carica</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001		yes			0,001	
<i>Hydrallmania falcata</i>	Cnidaria	Hydrozoa	quasi poisson	yes		0,001			yes	0,001			
<i>Iothia fulva</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Isohypisibius prosostomus</i>	Tardigrada	Eutardigrada	quasipoisson	yes				0,001	yes				0,001
<i>Kadosactis rosea</i>	Cnidaria	Anthozoa	quasipoisson	yes			0,001		yes		0,001		
<i>Karnekkampia sulcata</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes			0,001	
<i>Kellia suborbicularis</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
<i>Kelliella miliaris</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	
<i>Kophobelemnion stelliferum</i>	Cnidaria	Anthozoa	quasipoisson	yes				0,001	yes			0,001	
<i>Korethraster hispidus</i>	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes		0,001		
<i>Kurtiella bidentata</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Labioplax buskii</i>	Echinodermata	Holothuroidea	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Lacuna crassior</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes			0,001	
<i>Lacuna pallidula</i>	Mollusca	Gastropoda	poisson	none					none				
<i>Lacuna parva</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
<i>Lacuna vincta</i>	Mollusca	Gastropoda	poisson	yes		0,100	0,001	-0,001	yes		0,001	0,10	
<i>Laeocochlis sinistrata</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes			0,001	
<i>Lafoea dumosa</i>	Cnidaria	Hydrozoa	quasipoisson	none					none				
<i>Laona quadrata</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
<i>Ledella messanensis</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes			0,001	
<i>Lepeta caeca</i>	Mollusca	Gastropoda	quasipoisson	none					none				
<i>Lepidochitona cinerea</i>	Mollusca	Polyplacophora	quasipoisson	yes		0,001			yes		0,001		
<i>Leptaxinus minutus</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	0,001	yes		0,001	
<i>Leptochiton alveolus</i>	Mollusca	Polyplacophora	quasipoisson	yes		0,001	0,001	0,001	0,001	yes	0,001	0,001	
<i>Leptochiton arcticus</i>	Mollusca	Polyplacophora	poisson	yes		0,05	0,01	-0,001	yes		0,001	0,001	
<i>Leptochiton asellus</i>	Mollusca	Polyplacophora	quasipoisson	none					none				
<i>Leptychaster arcticus</i>	Echinodermata	Asteroidea	quasipoisson	none					none				
<i>Limacina helicina</i>	Mollusca	Gastropoda	quasipoisson	none					none				
<i>Limacina retroversa</i>	Mollusca	Gastropoda	quasipoisson	none					none				
<i>Limatula gwyni</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Limatula subauriculata</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes			0,001	
<i>Limnaea crassa</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Limopsis aurita</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Limopsis cristata</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	
<i>Limopsis minuta</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes		0,001	0,001	

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Liocyma fluctuosa</i>	Mollusca	Bivalvia	poisson	yes		-0,001		-0,001	yes		-0,001		
<i>Littorina littorea</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001		0,001	0,001	yes	0,001	0,001	
<i>Littorina saxatilis</i>	Mollusca	Gastropoda	quasipoisson	yes				-0,1	-0,05	yes	0,001	0,001	
<i>Lophaster furcifer</i>	Echinodermata	Asteroidea	poisson	none						yes	0,05		
<i>Lucinoma borealis</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001	0,001	yes	0,001	0,001	
<i>Luidia sarsii</i>	Echinodermata	Asteroidea	quasipoisson	yes					0,001	yes		0,001	
<i>Lyonsia arenosa</i>	Mollusca	Bivalvia	poisson	yes						yes	0,05		
<i>Lyonsiella abyssicola</i>	Mollusca	Bivalvia	quasipoisson	none						none			
<i>Macoma balthica</i>	Mollusca	Bivalvia	poisson	none						none			
<i>Macoma moesta</i>	Mollusca	Bivalvia	poisson	yes		-0,001				yes	-0,01		
<i>Macrobrotus richtersi</i>	Tardigrada	Eutardigrada	quasipoisson	yes					0,001	yes		0,001	
<i>Madrepora oculata</i>	Cnidaria	Anthozoa	quasipoisson	yes		0,001				yes	0,001		
<i>Mancikella divae</i>	Mollusca	Bivalvia	quasipoisson	yes					0,001	yes		0,001	
<i>Margarites helycinus</i>	Mollusca	Gastropoda	quasipoisson	none						none			
<i>Margarites olivaceus</i>	Mollusca	Gastropoda	quasipoisson	none						none			
<i>Margaritifera margaritifera</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001			yes	0,001	0,001	
<i>Mendicula ferruginosa</i>	Mollusca	Bivalvia	quasipoisson	none						none			
<i>Mendicula pygmaea</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001		yes	0,001	0,001	
<i>Metzgeria alba</i>	Mollusca	Gastropoda	quasipoisson	yes					0,001	yes		0,001	
<i>Modeeria rotunda</i>	Cnidaria	Hydrozoa	quasipoisson	yes				0,001		yes		0,001	
<i>Modiolula phaseolina</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001		yes	0,001	0,001	
<i>Moelleria costulata</i>	Mollusca	Gastropoda	quasipoisson	none						none			
<i>Mohnia mohni</i>	Mollusca	Gastropoda	poisson	none						none			
<i>Mohnia parva</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001		yes		0,001	
<i>Montacuta substriata</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001		yes	0,001	0,001	
<i>Musculus discors</i>	Mollusca	Bivalvia	quasipoisson	none						none			
<i>Musculus niger</i>	Mollusca	Bivalvia	quasipoisson	yes		-0,05				none			
<i>Mya arenaria</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001			0,001	yes		0,001	
<i>Myriotrochus rinkii</i>	Echinodermata	Holothuroidea	quasipoisson	yes				0,001		yes		0,001	
<i>Myriotrochus theeli</i>	Echinodermata	Holothuroidea	quasipoisson	yes					0,001	yes		0,001	
<i>Myriotrochus vitreus</i>	Echinodermata	Holothuroidea	quasipoisson	yes					0,001	yes		0,001	
<i>Mytilus edulis</i>	Mollusca	Bivalvia	poisson	none						none			

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Nephasoma lilljeborgii</i>	Annelida		quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Neptunea antiqua</i>	Mollusca	Gastropoda	poisson	yes	-0,01				none				
<i>Nucella lapillus</i>	Mollusca	Gastropoda	poisson	yes		-0,05		-0,001	yes				0,001
<i>Nucula nucleus</i>	Mollusca	Bivalvia	quasi poisson	yes		0,001		0,001	yes		0,001		0,001
<i>Nucula tumidula</i>	Mollusca	Bivalvia	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Nuculana minuta</i>	Mollusca	Bivalvia	poisson	yes	-0,001		-0,01	-0,001	yes		0,10		0,001
<i>Obelia dichotoma</i>	Cnidaria	Hydrozoa	quasi poisson	yes				0,001	yes				0,001
<i>Obelia longissima</i>	Cnidaria	Hydrozoa	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Odostomia unidentata</i>	Mollusca	Gastropoda	quasi poisson	yes			0,001		yes		0,001		
<i>Oenopota cinerea</i>	Mollusca	Gastropoda	quasi poisson	yes			0,001		yes			0,001	
<i>Oenopota elegans</i>	Mollusca	Gastropoda	quasi poisson	none					none				
<i>Oenopota pyramidalis</i>	Mollusca	Gastropoda	quasi poisson	yes			0,001		yes			0,001	
<i>Oenopota tenuicostata</i>	Mollusca	Gastropoda	quasi poisson	none					none				
<i>Onchidoris muricata</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001				yes	0,001			
<i>Onchnesoma squamatum</i>	Annelida		quasi poisson	yes			0,001	0,001	yes		0,001		0,001
<i>Onchnesoma steenstrupii</i>	Annelida		quasi poisson	yes			0,001	0,001	yes		0,001		0,001
<i>Onoba aculeus</i>	Mollusca	Gastropoda	poisson	none					none				
<i>Onoba semicostata</i>	Mollusca	Gastropoda	quasi poisson	yes		0,001	0,001		yes		0,001		0,001
<i>Ophiacantha abyssicola</i>	Echinodermata	Ophiuroidea	quasi poisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
<i>Ophiacantha bidentata</i>	Echinodermata	Ophiuroidea	quasi poisson	yes			-0,05	-0,05	none				
<i>Ophiactis abyssicola</i>	Echinodermata	Ophiuroidea	quasi poisson	yes				0,001	yes				0,001
<i>Ophiacten affinis</i>	Echinodermata	Ophiuroidea	quasi poisson	yes				0,001	yes				0,001
<i>Ophiacten gracilis</i>	Echinodermata	Ophiuroidea	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Ophiacten sericeum</i>	Echinodermata	Ophiuroidea	quasi poisson	yes			-0,05		none				
<i>Ophiolytus purpureus</i>	Echinodermata	Ophiuroidea	quasi poisson	yes	0,001			0,001	yes	0,001			0,001
<i>Ophiopholis aculeata</i>	Echinodermata	Ophiuroidea	quasi poisson	yes	-0,05	-0,05	-0,01	-0,001	yes		-0,1	-0,1	
<i>Ophiopleura borealis</i>	Echinodermata	Ophiuroidea	quasi poisson	none					none				
<i>Ophiopus arcticus</i>	Echinodermata	Ophiuroidea	quasi poisson	none					none				
<i>Ophiocollex glacialis</i>	Echinodermata	Ophiuroidea	quasi poisson	yes			-0,05	-0,05	none				
<i>Ophiura albida</i>	Echinodermata	Ophiuroidea	quasi poisson	yes				0,001	yes				0,001
<i>Ophiura carnea</i>	Echinodermata	Ophiuroidea	quasi poisson	yes				0,001	yes				0,001
<i>Ophiura robusta</i>	Echinodermata	Ophiuroidea	quasi poisson	yes		-0,1	-0,05	-0,05	none				

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET				
				CHANGES?	P2	P3	P4	P5	CHANGES?	W/o P2	W/o P3	W/o P4	W/o P5
<i>Palliolium striatum</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Palliolium tigrinum</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001	0,001	yes		0,001		0,001
<i>Pandora glacialis</i>	Mollusca	Bivalvia	poisson	none					none				
<i>Papillicardium minimum</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Paracuraria adunca</i>	Nematoda	Chromadorea	quasi poisson	yes				0,001	yes			0,001	
<i>Paragorgia arborea</i>	Cnidaria	Anthozoa	quasi poisson	yes	0,001				yes	0,001			
<i>Parastichopus tremulus</i>	Echinodermata	Holothuroidea	quasi poisson	yes				0,001	yes				0,001
<i>Parathyasira dunbari</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Parathyasira equalis</i>	Mollusca	Bivalvia	quasi poisson	yes					yes				0,10
<i>Parathyasira granulosa</i>	Mollusca	Bivalvia	quasi poisson	yes				0,001	yes				0,001
<i>Parvicardium pinnulatum</i>	Mollusca	Bivalvia	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Patella pellucida</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001				yes	0,001			
<i>Patella vulgata</i>	Mollusca	Gastropoda	quasi poisson	yes	0,001			0,001	yes	0,001			0,001
<i>Pecten maximus</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001		yes			0,001	
<i>Peregrina peregra</i>	Mollusca	Gastropoda	quasi poisson	yes	-0,001	0	-0,001	-0,001	yes	0,001	0,001	-0,001	-0,001
<i>Phakellia ventilabrum</i>	Porifera	Demospongiae	quasi poisson	yes				0,001	yes				0,001
<i>Phascalian strombus</i>	Annelida		quasi poisson	none					none				
<i>Plehnia arctica</i>	Platyhelminthes		poisson	none					none				
<i>Pleurobrachia pileus</i>	Ctenophora	Tentaculata	quasi poisson	yes		0,001	0,001		yes		0,001	0,001	
<i>Plicifusus kroyeri</i>	Mollusca	Gastropoda	poisson	none					none				
<i>Plotocnide borealis</i>	Cnidaria	Hydrozoa	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Pododesmus patelliformis</i>	Mollusca	Bivalvia	quasi poisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
<i>Policordia jeffreysi</i>	Mollusca	Bivalvia	quasi poisson	yes				0,001	yes				0,001
<i>Poliometra proluxa</i>	Echinodermata	Crinoidea	quasi poisson	yes			0,001		yes			0,001	
<i>Polycarpa fibrosa</i>	Chordata	Ascidacea	quasi poisson	yes				0,001	yes				0,001
<i>Polymastia mamillaris</i>	Porifera	Demospongiae	quasi poisson	yes			0,001		yes			0,001	
<i>Paromya granulata</i>	Mollusca	Bivalvia	quasi poisson	yes			0,001	0,001	yes			0,001	0,001
<i>Portlandia arctica</i>	Mollusca	Bivalvia	quasi poisson	none					none				
<i>Praephiline finmarchica</i>	Mollusca	Gastropoda	quasi poisson	yes				0,001	yes				0,001
<i>Priapulopsis bicaudatus</i>	Priapulida		quasi poisson	none					none				
<i>Primnoa resedaeformis</i>	Cnidaria	Anthozoa	quasi poisson	yes	0,001				yes	0,001			
<i>Propebela exarata</i>	Mollusca	Gastropoda	quasi poisson	none					none				

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Propebela harpularia</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Pseudarchaster parelii</i>	Echinodermata	Asteroidea	quasipoisson	yes				0,001		yes				0,001
<i>Pteraster militaris</i>	Echinodermata	Asteroidea	poisson	yes	-0,05			-0,001		yes	0,10			-0,05
<i>Ptychogasteria polaris</i>	Cnidaria	Hydrozoa	quasipoisson	none						none				
<i>Ptychogena crocea</i>	Cnidaria	Hydrozoa	quasipoisson	none						none				
<i>Pulsellum affine</i>	Mollusca	Scaphopoda	quasipoisson	yes				0,001		yes				0,001
<i>Pulsellum lafotense</i>	Mollusca	Scaphopoda	quasipoisson	yes		0,001				yes		0,001		0,001
<i>Punctulum wyvillethomsoni</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001		yes				0,001
<i>Puncturella noachina</i>	Mollusca	Gastropoda	quasipoisson	yes				-0,05		none				
<i>Pusillina inconspicua</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001			yes		0,001	0,001	
<i>Pycnanthus densus</i>	Cnidaria	Anthozoa	quasipoisson	none						none				
<i>Radiella sol</i>	Porifera	Demospongiae	quasipoisson	none						none				
<i>Retifusus latericeus</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Rhizocaulus verticillatus</i>	Cnidaria	Hydrozoa	quasipoisson	none						none				
<i>Rhizocrinus lafotensis</i>	Echinodermata	Crinoidea	poisson	none						yes				0,05
<i>Rissoa parva</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001			yes	0,001	0,001	0,001	
<i>Sarsia tubulosa</i>	Cnidaria	Hydrozoa	quasipoisson	yes			0,001			yes			0,001	
<i>Scaphander lignarius</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001	0,001		yes		0,001	0,001	0,001
<i>Scaphander punctostriatus</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Serripes groenlandicus</i>	Mollusca	Bivalvia	quasipoisson	yes			-0,05	-0,01		yes		-0,05	-0,05	-0,05
<i>Sertularella tenella</i>	Cnidaria	Hydrozoa	quasipoisson	yes			0,001			yes			0,001	
<i>Sertularia tenera</i>	Cnidaria	Hydrozoa	poisson	none						none				
<i>Similipecten similis</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Siphonodentalium laubieri</i>	Mollusca	Scaphopoda	quasipoisson	yes				0,001		yes				0,001
<i>Siphonodentalium lobatum</i>	Mollusca	Scaphopoda	quasipoisson	none						none				
<i>Skenea basistriata</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Skeneopsis planorbis</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001		0,001	0,001		yes	0,001		0,001	0,001
<i>Solariella obscura</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Spatangus purpureus</i>	Echinodermata	Echinoidea	quasipoisson	yes				0,001		yes				0,001
<i>Spatangus raschi</i>	Echinodermata	Echinoidea	quasipoisson	yes				0,001		yes				0,001
<i>Spirotropis monterosatoi</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001		yes				0,001
<i>Spisula elliptica</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001		yes				0,001

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Stagnicola palustris</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Staurostoma mertensii</i>	Cnidaria	Hydrozoa	quasipoisson	yes				0,001		yes				0,001
<i>Stegophiura nodosa</i>	Echinodermata	Ophiuroidea	poisson	yes	-0,001					yes	0,001			
<i>Stenosemus albus</i>	Mollusca	Polyplacophora	quasipoisson	none						none				
<i>Steromphala cineraria</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001		yes	0,001	0,001	0,001	0,001
<i>Steromphala tumida</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Symplectoscyphus tricuspidati</i>	Cnidaria	Hydrozoa	poisson	yes	-0,01					yes				
<i>Synoicum turgens</i>	Chordata	Ascidiacea	quasipoisson	yes		0,001				yes		0,001		
<i>Tachyrhynchus erosus</i>	Mollusca	Gastropoda	quasipoisson	yes			0,001			yes			0,001	
<i>Tachyrhynchus reticulatus</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Taranis moerchii</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001			yes		0,001	0,001	
<i>Tectura virginea</i>	Mollusca	Gastropoda	poisson	yes	0,001	0,05	-0,05	-0,001		yes	0,001	0,001	0,10	0,05
<i>Tellmya ferruginosa</i>	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001		yes			0,001	0,001
<i>Testudinalia testudinalis</i>	Mollusca	Gastropoda	poisson	yes	0,001		-0,1	-0,001		yes	0,001	0,05	0,001	0,001
<i>Thenea abyssorum</i>	Porifera	Demospongiae	quasipoisson	yes			0,001			yes				0,001
<i>Thesbia nana</i>	Mollusca	Gastropoda	quasipoisson	none						none				
<i>Thracia devexa</i>	Mollusca	Bivalvia	poisson	yes				-0,001		yes				none
<i>Thracia myopsis</i>	Mollusca	Bivalvia	quasipoisson	yes			-0,05	-0,1		yes	0,001			
<i>Thyasira flexuosa</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Thyasira gouldii</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Thyasira obsoleta</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Thyasira sarsii</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Timoclea ovata</i>	Mollusca	Bivalvia	quasipoisson	yes	0,001	0,001	0,001	0,001		yes	0,001	0,001	0,001	0,001
<i>Tonicella marmorea</i>	Mollusca	Polyplacophora	quasipoisson	none						none				
<i>Tremaster mirabilis</i>	Echinodermata	Asteroidea	quasipoisson	yes			0,001			yes			0,001	
<i>Tritia incrassata</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Trophonopsis barvicensis</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001		yes	0,001	0,001	0,001	0,001
<i>Turrisipho voeringi</i>	Mollusca	Gastropoda	quasipoisson	yes			0,001			yes			0,001	
<i>Turtonia minuta</i>	Mollusca	Bivalvia	quasipoisson	yes	0,001		0,001	0,001		yes	0,001		0,001	0,001
<i>Urticina felina</i>	Cnidaria	Anthozoa	quasipoisson	yes	0,001					yes	0,001			
<i>Valvata piscinalis</i>	Mollusca	Gastropoda	poisson	none						none				
<i>Varicorbula gibba</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001			yes		0,001	0,001	

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET					WITHOUT OFFSET					
				CHANGES?	P2	P3	P4	P5	CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5	
<i>Vitreolina philippi</i>	Mollusca	Gastropoda	quasipoisson	yes		0,001				yes		0,001		
<i>Vitrina pellucida</i>	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001				yes	0,001	0,001		
<i>Yaldiella annenkovae</i>	Mollusca	Bivalvia	quasipoisson	yes				0,001		yes				0,001
<i>Yaldiella frigida</i>	Mollusca	Bivalvia	quasipoisson	yes			-0,1	0,05		yes	0,05		-0,05	-0,1
<i>Yaldiella intermedia</i>	Mollusca	Bivalvia	poisson	none						yes			0,05	
<i>Yaldiella lenticula</i>	Mollusca	Bivalvia	poisson	yes	0,001	0,05				yes	0,001	0,001	0,001	0,001
<i>Yaldiella lucida</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Yaldiella nana</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Yaldiella philippiana</i>	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001		yes		0,001	0,001	0,001
<i>Yaldiella propinqua</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Yaldiella solidula</i>	Mollusca	Bivalvia	quasipoisson	none						none				
<i>Ziminella salmonacea</i>	Mollusca	Gastropoda	quasipoisson	yes				0,001		yes				0,001

## Df\_model dataset

The Df\_model dataset part1 was used to calculate the offset for the log linear models, and part 2 was used for the Correspondence analysis.

N: Raw number of occurrences; R: relative occurrence to the total number of observations in the given period

### Part 1: Occurrences of invertebrates in the Barents Sea as downloaded from GBIF after data cleaning.

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Abra longicallus</i>					26	0.450%	39	0.277%	128	0.378%
<i>Abra nitida</i>									62	0.183%
<i>Abra prismatica</i>									15	0.044%
<i>Acanthocardia echinata</i>									28	0.083%
<i>Acanthotrochus mirabilis</i>							19	0.135%	12	0.035%
<i>Acis sarsi</i>									11	0.032%
<i>Admete viridula</i>			13	0.119%	59	1.022%	54	0.384%	26	0.077%
<i>Adontorhina similis</i>					23	0.398%	19	0.135%	293	0.865%
<i>Aeginopsis laurentii</i>			15	0.137%	146	2.529%	312	2.219%	288	0.851%
<i>Aeolidia papillosa</i>			13	0.119%						
<i>Aglantha digitale</i>			62	0.567%	102	1.767%	594	4.224%	716	2.115%
<i>Akera bullata</i>			23	0.210%						
<i>Allantactis parasitica</i>	12	0.275%			12	0.208%	24	0.171%		
<i>Alvania cimicoides</i>					23	0.398%				
<i>Alvania punctura</i>					20	0.347%				
<i>Alvania subsoluta</i>									14	0.041%
<i>Amauropsis islandica</i>			26	0.238%			13	0.092%		
<i>Amphilepis norvegica</i>									16	0.047%
<i>Amphipholis squamata</i>							111	0.789%	1105	3.264%
<i>Amphiura borealis</i>							25	0.178%	294	0.868%
<i>Amphiura filiformis</i>									21	0.062%
<i>Amphiura securigera</i>							18	0.128%		
<i>Anatoma crispata</i>					41	0.710%	21	0.149%	24	0.071%
<i>Antalis agilis</i>							19	0.135%	36	0.106%
<i>Antalis entalis</i>					45	0.780%	76	0.540%	347	1.025%
<i>Antalis occidentalis</i>							48	0.341%	316	0.933%
<i>Aplysilla sulfurea</i>									131	0.387%
<i>Aporrhais pespelecani</i>			24	0.220%	32	0.554%	15	0.107%	12	0.035%
<i>Arctica islandica</i>	11	0.252%	32	0.293%	16	0.277%	36	0.256%	54	0.160%
<i>Ariadnaria borealis</i>			88	0.805%	22	0.381%	15	0.107%	37	0.109%
<i>Arianta arbustorum</i>			13	0.119%						
<i>Arion fuscus</i>			15	0.137%						
<i>Ascidia obliqua</i>					12	0.208%				
<i>Astarte crenata</i>	30	0.688%	14	0.128%	50	0.866%	104	0.740%	111	0.328%
<i>Astarte elliptica</i>	58	1.330%	31	0.284%	27	0.468%	46	0.327%	68	0.201%
<i>Astarte montagui</i>	89	2.040%	60	0.549%	42	0.728%	78	0.555%	63	0.186%
<i>Astarte sulcata</i>					51	0.884%	128	0.910%	911	2.691%
<i>Asterias rubens</i>									31	0.092%
<i>Astyris rosacea</i>			13	0.119%	13	0.225%				
<i>Aulactinia stella</i>			17	0.156%						
<i>Aurelia aurita</i>							290	2.062%	29	0.086%
<i>Axinopsida orbiculata</i>	22	0.504%	11	0.101%			28	0.199%	15	0.044%
<i>Axinulus croulinensis</i>					12	0.208%			47	0.139%
<i>Bathyarca frielei</i>							11	0.078%	21	0.062%
<i>Bathyarca pectunculoides</i>			22	0.201%	27	0.468%	227	1.614%	1098	3.243%
<i>Bathycrinus carpenterii</i>							55	0.391%	23	0.068%
<i>Bathyomphalus contortus</i>					16	0.277%				
<i>Bathypolypus arcticus</i>							24	0.171%		
<i>Beroe cucumis</i>			12	0.110%	35	0.606%	72	0.512%	43	0.127%
<i>Bolinopsis infundibulum</i>					32	0.554%				
<i>Boltenia echinata</i>					26	0.450%				
<i>Boreacola maltzani</i>							13	0.092%		
<i>Boreochiton ruber</i>	11	0.252%	117	1.070%	55	0.953%				
<i>Boreotrophon clathratus</i>			100	0.915%	40	0.693%	24	0.171%	21	0.062%
<i>Boreotrophon clavatus</i>									15	0.044%
<i>Boreotrophon truncatus</i>			27	0.247%	23	0.398%	41	0.292%	20	0.059%

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Botrylloides aureus</i>			12	0.110%	16	0.277%				
<i>Bougainvillia superciliaris</i>							14	0.100%	30	0.089%
<i>Brattegardia nansenii</i>			30	0.274%						
<i>Brisaster fragilis</i>									32	0.095%
<i>Brissopsis lyrifera</i>									14	0.041%
<i>Buccinum cyaneum</i>			79	0.723%	11	0.191%				
<i>Buccinum finmarkianum</i>			16	0.146%						
<i>Cactosoma abyssorum</i>							24	0.171%		
<i>Cadulus jeffreysi</i>									20	0.059%
<i>Cadulus propinquus</i>									244	0.721%
<i>Cadulus subfusiformis</i>									13	0.038%
<i>Calliostoma occidentale</i>			24	0.220%					19	0.056%
<i>Calycella syringa</i>			17	0.156%						
<i>Campanularia volubilis</i>	12	0.275%	20	0.183%						
<i>Capulus ungaricus</i>					13	0.225%			15	0.044%
<i>Cardiomya cadiziana</i>									34	0.100%
<i>Ceramaster granularis</i>							25	0.178%	29	0.086%
<i>Cerastoderma edule</i>			12	0.110%	16	0.277%				
<i>Cerithiella metula</i>					14	0.243%	16	0.114%	41	0.121%
<i>Chaetoderma nitidulum</i>					15	0.260%				
<i>Chamelea striatula</i>			26	0.238%			11	0.078%	14	0.041%
<i>Cladorhiza gelida</i>							24	0.171%		
<i>Clausilia bidentata</i>			16	0.146%						
<i>Clelandella miliaris</i>					22	0.381%				
<i>Clione limacina</i>			39	0.357%	73	1.265%	177	1.259%	165	0.487%
<i>Colus gracilis</i>			23	0.210%	14	0.243%	12	0.085%	22	0.065%
<i>Coryphella verrucosa</i>			12	0.110%						
<i>Crenella decussata</i>					58	1.005%	73	0.519%	110	0.325%
<i>Crossaster papposus</i>	87	1.994%	77	0.704%					23	0.068%
<i>Ctenodiscus crispatus</i>							28	0.199%	25	0.074%
<i>Curtitoma trevillianii</i>					40	0.693%	41	0.292%		
<i>Curtitoma violacea</i>					11	0.191%	13	0.092%		
<i>Cuspidaria lamellosa</i>					14	0.243%	113	0.804%	760	2.245%
<i>Cuspidaria obesa</i>							46	0.327%	159	0.470%
<i>Cuspidaria subtorta</i>			12	0.110%			36	0.256%	33	0.097%
<i>Cyanea capillata</i>							280	1.991%	24	0.071%
<i>Cyclopecten hoskynsi</i>	26	0.596%	83	0.759%	30	0.520%	68	0.484%	556	1.642%
<i>Cylista splendens</i>							24	0.171%		
<i>Cyrellia aequalis</i>					12	0.208%				
<i>Cyrellia linearis</i>					25	0.433%				
<i>Dacrydium ockelmanni</i>							103	0.732%	893	2.638%
<i>Dacrydium vitreum</i>	76	1.742%	216	1.976%	93	1.611%	80	0.569%	649	1.917%
<i>Delectopecten vitreus</i>			21	0.192%	11	0.191%	32	0.228%	153	0.452%
<i>Dendrodoa aggregata</i>					19	0.329%				
<i>Dendrodoa grossularia</i>					16	0.277%				
<i>Dendronotus frondosus</i>			28	0.256%			20	0.142%	14	0.041%
<i>Desmophyllum pertusum</i>			75	0.686%						
<i>Diaphana hiemalis</i>									14	0.041%
<i>Didemnum albidum</i>					12	0.208%				
<i>Dimophyes arctica</i>			19	0.174%						
<i>Diplodonta torelli</i>	18	0.413%								
<i>Doto coronata</i>			14	0.128%						
<i>Echinocardium flavescens</i>									18	0.053%
<i>Echinocyamus pusillus</i>									25	0.074%
<i>Echinus esculentus</i>									134	0.396%
<i>Elpidia belyaevi</i>							14	0.100%		

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Elpidia glacialis</i>							30	0.213%	24	0.071%
<i>Emarginula crassa</i>					13	0.225%				
<i>Ennucula convexa</i>									12	0.035%
<i>Ennucula corticata</i>					23	0.398%	30	0.213%	120	0.354%
<i>Ennucula tenuis</i>	51	1.169%	56	0.512%	58	1.005%	113	0.804%	168	0.496%
<i>Entalina tetragona</i>							18	0.128%	69	0.204%
<i>Epizoanthus papillosus</i>							24	0.171%	65	0.192%
<i>Erginus rubellus</i>	13	0.298%					14	0.100%		
<i>Euconulus fulvus</i>			26	0.238%						
<i>Eudendrium capillare</i>							24	0.171%		
<i>Eudendrium ramosum</i>							24	0.171%		
<i>Eulima bilineata</i>					14	0.243%	15	0.107%	35	0.103%
<i>Eulimella scillae</i>									12	0.035%
<i>Eumetula arctica</i>					13	0.225%				
<i>Eupyrigus scaber</i>							32	0.228%		
<i>Euspira montagui</i>					71	1.230%	50	0.356%	168	0.496%
<i>Euspira nitida</i>					20	0.347%			26	0.077%
<i>Flabellum macandrewi</i>									13	0.038%
<i>Frigidoalvania janmayeni</i>							33	0.235%		
<i>Galba truncatula</i>	19	0.436%			25	0.433%				
<i>Genaxinus eumyariis</i>							15	0.107%	72	0.213%
<i>Glandulactis spetsbergensis</i>							24	0.171%		
<i>Golfingia margaritacea</i>							46	0.327%	32	0.095%
<i>Golfingia vulgaris</i>							92	0.654%	51	0.151%
<i>Gorgonocephalus arcticus</i>			49	0.448%						
<i>Gorgonocephalus eucnemis</i>	14	0.321%	56	0.512%	16	0.277%				
<i>Gracilechinus acutus</i>									27	0.080%
<i>Grammaria abietina</i>							24	0.171%		
<i>Gyraulus acronicus</i>	29	0.665%	24	0.220%	59	1.022%	13	0.092%		
<i>Gyrodactylus albalacustris</i>									11	0.032%
<i>Gyrodactylus arcuatus</i>							16	0.114%	55	0.162%
<i>Halcampa arctica</i>	21	0.481%								
<i>Halecium beanii</i>							24	0.171%		
<i>Halecium labrosum</i>	12	0.275%					24	0.171%		
<i>Haliella stenostoma</i>			21	0.192%			23	0.164%	64	0.189%
<i>Halitholus yoldiaearticae</i>							30	0.213%	24	0.071%
<i>Halocynthia pyriformis</i>					17	0.295%			138	0.408%
<i>Hanleya hanleyi</i>			21	0.192%	44	0.762%	14	0.100%	24	0.071%
<i>Henricia perforata</i>									46	0.136%
<i>Henricia sanguinolenta</i>									56	0.165%
<i>Hermania scabra</i>					12	0.208%	18	0.128%	12	0.035%
<i>Heteranomia squamula</i>			64	0.585%	12	0.208%	33	0.235%	429	1.267%
<i>Hiatella rugosa</i>							18	0.128%	22	0.065%
<i>Hippasteria phrygiana</i>							26	0.185%	11	0.032%
<i>Hormathia digitata</i>			24	0.220%	39	0.676%	24	0.171%		
<i>Hormathia nodosa</i>	18	0.413%					24	0.171%		
<i>Hydractinia carica</i>							24	0.171%		
<i>Hydrallmania falcata</i>			13	0.119%						
<i>Iothia fulva</i>			27	0.247%	35	0.606%	18	0.128%	17	0.050%
<i>Isohypsibius prosostomus</i>									12	0.035%
<i>Kadosactis rosea</i>							24	0.171%		
<i>Karnekampia sulcata</i>									159	0.470%
<i>Kellia suborbicularis</i>					19	0.329%	11	0.078%		
<i>Kelliella miliaris</i>					12	0.208%	18	0.128%	82	0.242%
<i>Kophobelemnon stelliferum</i>									17	0.050%
<i>Korethraster hispidus</i>							24	0.171%		

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Kurtiella bidentata</i>							11	0.078%	24	0.071%
<i>Labidoplax buskii</i>							51	0.363%	1144	3.379%
<i>Lacuna crassior</i>							14	0.100%		
<i>Lacuna pallidula</i>			41	0.375%			19	0.135%		
<i>Lacuna parva</i>			19	0.174%						
<i>Lacuna vincta</i>	13	0.298%	72	0.659%	88	1.525%	56	0.398%	25	0.074%
<i>Laeocochlis sinistrata</i>									23	0.068%
<i>Lafoea dumosa</i>	16	0.367%	26	0.238%	47	0.814%	24	0.171%		
<i>Laona quadrata</i>			20	0.183%						
<i>Ledella messanensis</i>									27	0.080%
<i>Lepeta caeca</i>	41	0.940%	154	1.409%	88	1.525%	69	0.491%	138	0.408%
<i>Lepidochitona cinerea</i>			17	0.156%						
<i>Leptaxinus minutus</i>							17	0.121%	199	0.588%
<i>Leptochiton alveolus</i>			13	0.119%	45	0.780%	42	0.299%	32	0.095%
<i>Leptochiton arcticus</i>	12	0.275%	71	0.650%	59	1.022%			16	0.047%
<i>Leptochiton asellus</i>			36	0.329%	118	2.044%	44	0.313%	47	0.139%
<i>Leptychaster arcticus</i>							27	0.192%	49	0.145%
<i>Limacina helicina</i>			45	0.412%	39	0.676%	127	0.903%	156	0.461%
<i>Limacina retroversa</i>			50	0.457%					20	0.059%
<i>Limatula gwyni</i>							18	0.128%	269	0.795%
<i>Limatula subauriculata</i>									27	0.080%
<i>Limea crassa</i>							22	0.156%	125	0.369%
<i>Limopsis aurita</i>							59	0.420%	34	0.100%
<i>Limopsis cristata</i>							60	0.427%	541	1.598%
<i>Limopsis minuta</i>							75	0.533%	133	0.393%
<i>Liocyma fluctuosa</i>	50	1.146%	58	0.531%			13	0.092%		
<i>Littorina littorea</i>			120	1.098%			16	0.114%	25	0.074%
<i>Littorina obtusata</i>	14	0.321%	248	2.269%	13	0.225%	27	0.192%	33	0.097%
<i>Littorina saxatilis</i>	35	0.802%	260	2.379%	25	0.433%	37	0.263%	52	0.154%
<i>Lophaster furcifer</i>	17	0.390%	31	0.284%			24	0.171%		
<i>Lucinoma borealis</i>			14	0.128%			17	0.121%	15	0.044%
<i>Luidia sarsii</i>									12	0.035%
<i>Lyonsia arenaosa</i>	51	1.169%	79	0.723%						
<i>Lyonsiella abyssicola</i>							41	0.292%	604	1.784%
<i>Macoma balthica</i>			38	0.348%			24	0.171%	16	0.047%
<i>Macoma moesta</i>	36	0.825%	15	0.137%						
<i>Macrobotus richtersi</i>									28	0.083%
<i>Madrepora oculata</i>			123	1.125%						
<i>Mancikellia divae</i>									31	0.092%
<i>Margarites helicinus</i>			137	1.253%	39	0.676%	44	0.313%	27	0.080%
<i>Margarites olivaceus</i>	13	0.298%	11	0.101%			38	0.270%	33	0.097%
<i>Margaritifera margaritifera</i>					30	0.520%	35	0.249%		
<i>Mendicula ferruginosa</i>					26	0.450%	32	0.228%	221	0.653%
<i>Mendicula pygmaea</i>							73	0.519%	46	0.136%
<i>Metzgeria alba</i>									14	0.041%
<i>Modeeria rotunda</i>							24	0.171%		
<i>Modiolula phaseolina</i>					48	0.832%	42	0.299%	213	0.629%
<i>Moelleria costulata</i>					18	0.312%	25	0.178%	11	0.032%
<i>Mohnia mohni</i>							12	0.085%	14	0.041%
<i>Mohnia parva</i>							24	0.171%		
<i>Montacuta substriata</i>							11	0.078%	26	0.077%
<i>Musculus discors</i>			45	0.412%	12	0.208%	33	0.235%	34	0.100%
<i>Musculus niger</i>	34	0.779%	19	0.174%	31	0.537%	69	0.491%	45	0.133%
<i>Mya arenaria</i>			14	0.128%					12	0.035%
<i>Myriotrochus rinkii</i>							26	0.185%		
<i>Myriotrochus theeli</i>									11	0.032%

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Myriotrochus vitreus</i>									22	0.065%
<i>Mytilus edulis</i>			138	1.262%	11	0.191%	891	6.336%	192	0.567%
<i>Nephasoma lilljeborgii</i>							19	0.135%	23	0.068%
<i>Neptunea antiqua</i>	21	0.481%	12	0.110%	17	0.295%				
<i>Nucella lapillus</i>	15	0.344%	177	1.619%	16	0.277%	748	5.319%	80	0.236%
<i>Nucula nucleus</i>					19	0.329%			34	0.100%
<i>Nucula tumidula</i>					12	0.208%	57	0.405%	198	0.585%
<i>Nuculana minuta</i>	18	0.413%	12	0.110%	31	0.537%	25	0.178%	52	0.154%
<i>Obelia dichotoma</i>									77	0.227%
<i>Obelia longissima</i>							15	0.107%		
<i>Odostomia unidentata</i>					17	0.295%				
<i>Oenopota cinerea</i>							25	0.178%		
<i>Oenopota elegans</i>					22	0.381%	16	0.114%		
<i>Oenopota pyramidalis</i>							28	0.199%		
<i>Oenopota tenuicostata</i>					20	0.347%	22	0.156%	30	0.089%
<i>Onchidoris muricata</i>			18	0.165%						
<i>Onchnesoma squamatum</i>							91	0.647%	237	0.700%
<i>Onchnesoma steenstrupii</i>							58	0.412%	168	0.496%
<i>Onoba aculeus</i>			120	1.098%			17	0.121%	11	0.032%
<i>Onoba semicostata</i>					28	0.485%	19	0.135%		
<i>Ophiacantha abyssicola</i>			13	0.119%			48	0.341%	142	0.419%
<i>Ophiacantha bidentata</i>	420	9.629%	633	5.791%	78	1.351%	59	0.420%	178	0.526%
<i>Ophiactis abyssicola</i>									21	0.062%
<i>Ophiacten affinis</i>									1131	3.341%
<i>Ophiacten gracilis</i>							17	0.121%	136	0.402%
<i>Ophiacten sericeum</i>	137	3.141%	419	3.833%	68	1.178%	59	0.420%	98	0.289%
<i>Ophiolytus purpureus</i>			13	0.119%					27	0.080%
<i>Ophiopholis aculeata</i>	418	9.583%	444	4.062%	48	0.832%	53	0.377%	263	0.777%
<i>Ophiopleura borealis</i>			103	0.942%	48	0.832%	24	0.171%	36	0.106%
<i>Ophiopus arcticus</i>			42	0.384%	13	0.225%	36	0.256%	24	0.071%
<i>Ophioscolex glacialis</i>	85	1.949%	138	1.262%	26	0.450%	29	0.206%	57	0.168%
<i>Ophiura albida</i>									29	0.086%
<i>Ophiura carnea</i>									55	0.162%
<i>Ophiura robusta</i>	247	5.663%	420	3.842%	33	0.572%	66	0.469%	258	0.762%
<i>Palliolum striatum</i>					16	0.277%			18	0.053%
<i>Palliolum tigrinum</i>					11	0.191%			11	0.032%
<i>Pandora glacialis</i>	21	0.481%								
<i>Papillicardium minimum</i>					40	0.693%	61	0.434%	1113	3.288%
<i>Paracuaria adunca</i>							12	0.085%		
<i>Paragorgia arborea</i>			12	0.110%						
<i>Parastichopus tremulus</i>									46	0.136%
<i>Parathyasira dunbari</i>							38	0.270%	260	0.768%
<i>Parathyasira equalis</i>	47	1.077%	119	1.089%	39	0.676%	65	0.462%	279	0.824%
<i>Parathyasira granulosa</i>									32	0.095%
<i>Parvicardium pinnulatum</i>					44	0.762%	41	0.292%	85	0.251%
<i>Patella pellucida</i>			32	0.293%						
<i>Patella vulgata</i>			24	0.220%					18	0.053%
<i>Pecten maximus</i>							138	0.981%		
<i>Peregriana peregra</i>	19	0.436%	21	0.192%	133	2.304%	17	0.121%	12	0.035%
<i>Phakellia ventilabrum</i>									133	0.393%
<i>Phascolion strombus</i>							53	0.377%	160	0.473%
<i>Plehnia arctica</i>	81	1.857%								
<i>Pleurobrachia pileus</i>					11	0.191%	24	0.171%		
<i>Plicifusus kroyeri</i>	19	0.436%								
<i>Plotocnide borealis</i>					38	0.658%	78	0.555%	93	0.275%
<i>Pododesmus patelliformis</i>					16	0.277%	14	0.100%	12	0.035%

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Policordia jeffreysi</i>									24	0.071%
<i>Poliometra proluxa</i>							24	0.171%		
<i>Polycarpa fibrosa</i>									451	1.332%
<i>Polymastia mamillaris</i>							24	0.171%		
<i>Poromya granulata</i>							15	0.107%	129	0.381%
<i>Portlandia arctica</i>			21	0.192%			12	0.085%	15	0.044%
<i>Praeophiline finmarchica</i>									28	0.083%
<i>Priapulopsis bicaudatus</i>							24	0.171%		
<i>Primnoa resedaeformis</i>			23	0.210%						
<i>Propebela exarata</i>							12	0.085%		
<i>Propebela harpularia</i>					14	0.243%				
<i>Pseudarchaster parelii</i>									18	0.053%
<i>Pteraster militaris</i>	26	0.596%	42	0.384%					13	0.038%
<i>Ptychogasteria polaris</i>							24	0.171%		
<i>Ptychogena crocea</i>							24	0.171%		
<i>Pulsellum affine</i>									68	0.201%
<i>Pulsellum lofotense</i>					13	0.225%			25	0.074%
<i>Punctulum wyvillethomsoni</i>									45	0.133%
<i>Puncturella noachina</i>	35	0.802%	128	1.171%	90	1.559%	46	0.327%	94	0.278%
<i>Pusillina inconspicua</i>					18	0.312%	17	0.121%		
<i>Pycnanthus densus</i>							24	0.171%		
<i>Radiella sol</i>							26	0.185%		
<i>Retifusus latericeus</i>							25	0.178%		
<i>Rhizocaulus verticillatus</i>							24	0.171%		
<i>Rhizocrinus lofotensis</i>									16	0.047%
<i>Rissoa parva</i>			16	0.146%	20	0.347%	11	0.078%		
<i>Sarsia tubulosa</i>							18	0.128%		
<i>Scaphander lignarius</i>					14	0.243%	15	0.107%	16	0.047%
<i>Scaphander punctostriatus</i>			34	0.311%	24	0.416%	11	0.078%	54	0.160%
<i>Serripes groenlandicus</i>	78	1.788%	104	0.951%	18	0.312%	18	0.128%	14	0.041%
<i>Sertularella tenella</i>							24	0.171%		
<i>Sertularia tenera</i>	15	0.344%					24	0.171%		
<i>Similipecten similis</i>					35	0.606%	20	0.142%	75	0.222%
<i>Siphonodentalium laubieri</i>									216	0.638%
<i>Siphonodentalium lobatum</i>							98	0.697%	150	0.443%
<i>Skenea basistriata</i>					14	0.243%				
<i>Skeneopsis planorbis</i>			81	0.741%			38	0.270%	17	0.050%
<i>Solariella obscura</i>			16	0.146%			17	0.121%	21	0.062%
<i>Spatangus purpureus</i>									17	0.050%
<i>Spatangus raschi</i>									11	0.032%
<i>Spirotropis monterosatoi</i>									11	0.032%
<i>Spisula elliptica</i>									15	0.044%
<i>Stagnicola palustris</i>	17	0.390%								
<i>Staurostoma mertensii</i>							24	0.171%		
<i>Stegophiura nodosa</i>	169	3.874%	269	2.461%						
<i>Stenosemus albus</i>			113	1.034%	199	3.448%	83	0.590%	47	0.139%
<i>Steromphala cineraria</i>			122	1.116%	37	0.641%	14	0.100%	25	0.074%
<i>Steromphala tumida</i>			54	0.494%	64	1.109%	34	0.242%	28	0.083%
<i>Symplectoscyphus tricuspidatus</i>	19	0.436%	11	0.101%						
<i>Synoicum turgens</i>					23	0.398%				
<i>Tachyrhynchus erosus</i>							26	0.185%		
<i>Tachyrhynchus reticulatus</i>	20	0.459%								
<i>Taranis moerchii</i>					15	0.260%	16	0.114%		
<i>Tectura virginea</i>	11	0.252%	110	1.006%	57	0.988%	22	0.156%	25	0.074%
<i>Tellimya ferruginosa</i>							11	0.078%	26	0.077%
<i>Testudinalia testudinalis</i>	19	0.436%	210	1.921%	39	0.676%	57	0.405%	21	0.062%

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
<i>Thenea abyssorum</i>							14	0.100%		
<i>Thesbia nana</i>					29	0.502%	12	0.085%	14	0.041%
<i>Thracia devexa</i>	11	0.252%							20	0.059%
<i>Thracia myopsis</i>	80	1.834%	168	1.537%	32	0.554%	54	0.384%	46	0.136%
<i>Thyasira flexuosa</i>					15	0.260%	20	0.142%	44	0.130%
<i>Thyasira gouldii</i>					18	0.312%	41	0.292%	127	0.375%
<i>Thyasira obsoleta</i>					21	0.364%	208	1.479%	1485	4.386%
<i>Thyasira sarsii</i>							43	0.306%	40	0.118%
<i>Timoclea ovata</i>			17	0.156%	20	0.347%	16	0.114%	45	0.133%
<i>Tonicella marmorea</i>	12	0.275%	91	0.832%	141	2.443%	62	0.441%	99	0.292%
<i>Tremaster mirabilis</i>							24	0.171%		
<i>Tritia incrassata</i>					30	0.520%				
<i>Trophonopsis barvicensis</i>			11	0.101%	21	0.364%	14	0.100%	12	0.035%
<i>Turrisipho voeringi</i>							30	0.213%		
<i>Turtonia minuta</i>			27	0.247%			34	0.242%	11	0.032%
<i>Urticina felina</i>			17	0.156%						
<i>Valvata piscinalis</i>	12	0.275%								
<i>Varicorbula gibba</i>					11	0.191%	11	0.078%		
<i>Vitreolina philippi</i>					11	0.191%				
<i>Vitrina pellucida</i>			26	0.238%	13	0.225%				
<i>Yoldiella annenkovae</i>									34	0.100%
<i>Yoldiella frigida</i>	38	0.871%	98	0.897%	21	0.364%	11	0.078%	13	0.038%
<i>Yoldiella intermedia</i>	50	1.146%	324	2.964%	67	1.161%	68	0.484%	33	0.097%
<i>Yoldiella lenticula</i>	25	0.573%	315	2.882%	62	1.074%	109	0.775%	299	0.883%
<i>Yoldiella lucida</i>					35	0.606%	156	1.109%	898	2.653%
<i>Yoldiella nana</i>					38	0.658%	96	0.683%	856	2.529%
<i>Yoldiella philippiana</i>					25	0.433%	28	0.199%	74	0.219%
<i>Yoldiella propinqua</i>							67	0.476%	616	1.820%
<i>Yoldiella solidula</i>			13	0.119%			32	0.228%	465	1.374%
<i>Ziminella salmonacea</i>									17	0.050%

## Part 2: Occurrences of invertebrates in the Barents Sea sorted into time period and geographic zone.

0 = occurrence less than 10 per period · zone

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Abra longicallus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128
<i>Abra nitida</i>	0	0	0	0	0	0	0	0	26	0	0	39	0	0	62
<i>Abra prismatica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
<i>Acanthocardia echinata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	26
<i>Acanthorhynchus mirabilis</i>	0	0	0	0	0	0	0	0	0	0	0	19	0	0	12
<i>Aclis sarsi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
<i>Admete viridula</i>	0	0	0	2	0	11	0	3	56	5	24	25	0	7	19
<i>Adontorhina similis</i>	0	0	0	0	0	0	0	0	23	0	0	19	0	0	293
<i>Aeginopsis laurentii</i>	0	0	0	9	5	1	3	15	128	0	0	312	0	0	288
<i>Aeolidia papillosa</i>	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
<i>Aglantha digitale</i>	0	0	0	2	7	53	1	4	97	0	0	594	0	2	714
<i>Akera bullata</i>	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0
<i>Allantactis parasitica</i>	0	11	1	0	0	0	1	11	0	5	18	1	0	0	0
<i>Alvania cimicoides</i>	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0
<i>Alvania punctura</i>	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
<i>Alvania subsoluta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
<i>Amauropsis islandica</i>	0	0	0	0	0	26	0	0	0	0	5	8	0	0	0
<i>Amphilepis norvegica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
<i>Amphipholis squamata</i>	0	0	0	0	0	0	0	0	0	0	0	111	0	0	1105
<i>Amphiura borealis</i>	0	0	0	0	0	0	0	0	0	0	0	25	0	0	294
<i>Amphiura filiformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
<i>Amphiura securigera</i>	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0
<i>Anatoma crispata</i>	0	0	0	0	0	0	0	0	41	0	4	17	0	0	24
<i>Antalis agilis</i>	0	0	0	0	0	0	0	0	0	0	0	19	0	0	36
<i>Antalis entalis</i>	0	0	0	0	0	0	0	0	45	0	1	75	0	0	347
<i>Antalis occidentalis</i>	0	0	0	0	0	0	0	0	0	0	0	48	0	0	316
<i>Aplysilla sulfurea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	131	0
<i>Aporrhais pespelecani</i>	0	0	0	0	0	24	0	0	32	0	0	15	0	0	12
<i>Arctica islandica</i>	0	2	9	0	1	31	0	0	16	0	0	36	0	1	53
<i>Ariadnaria borealis</i>	0	0	0	0	0	88	0	0	22	0	1	14	0	1	36
<i>Arianta arbustorum</i>	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
<i>Arian fuscus</i>	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
<i>Ascidia obliqua</i>	0	0	0	0	0	0	0	1	11	0	0	0	0	0	0
<i>Astarte crenata</i>	0	15	15	0	12	2	0	20	30	0	17	87	0	18	93
<i>Astarte elliptica</i>	4	40	14	0	20	11	0	1	26	0	24	22	0	2	66
<i>Astarte montagui</i>	7	68	14	0	50	10	1	1	40	0	30	48	0	12	51

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Astorte sulcata</i>	0	0	0	0	0	0	0	1	50	0	1	127	0	6	905
<i>Asterias rubens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
<i>Astyris rosacea</i>	0	0	0	0	1	12	0	0	13	0	0	0	0	0	0
<i>Aulactinia stella</i>	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
<i>Aurelia aurita</i>	0	0	0	0	0	0	0	0	0	0	0	290	0	0	29
<i>Axinopsida orbiculata</i>	0	21	1	0	11	0	0	0	0	0	24	4	0	14	1
<i>Axinulus croulinensis</i>	0	0	0	0	0	0	0	0	12	0	0	0	0	0	47
<i>Bathyarca frielei</i>	0	0	0	0	0	0	0	0	0	0	0	11	0	3	18
<i>Bathyarca pectunculoides</i>	0	0	0	0	1	21	0	0	27	5	18	204	0	2	1096
<i>Bathyrinus carpenterii</i>	0	0	0	0	0	0	0	0	0	6	20	29	1	1	21
<i>Bathymphalus contortus</i>	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
<i>Bathypolypus arcticus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Beroe cucumis</i>	0	0	0	0	2	10	0	1	34	0	0	72	0	0	43
<i>Bolinopsis infundibulum</i>	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
<i>Boltenia echinata</i>	0	0	0	0	0	0	0	23	3	0	0	0	0	0	0
<i>Borecola maltzani</i>	0	0	0	0	0	0	0	0	0	0	7	6	0	0	0
<i>Boreochiton ruber</i>	0	0	11	0	1	116	0	4	51	0	0	0	0	0	0
<i>Boreotrophon clathratus</i>	0	0	0	0	2	98	0	0	40	0	5	19	0	0	21
<i>Boreotrophon clavatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
<i>Boreotrophon truncatus</i>	0	0	0	0	0	27	0	3	20	5	22	14	0	0	20
<i>Botrylloides aureus</i>	0	0	0	0	0	12	0	10	6	0	0	0	0	0	0
<i>Bougainvillia superciliaris</i>	0	0	0	0	0	0	0	0	0	0	0	14	0	0	30
<i>Brattegardia nansenii</i>	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0
<i>Brisaster fragilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
<i>Brissopsis lyrifera</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
<i>Buccinum cyaneum</i>	0	0	0	2	16	61	0	11	0	0	0	0	0	0	0
<i>Buccinum finmarkianum</i>	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
<i>Cactosoma abyssorum</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Cadulus jeffreysi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
<i>Cadulus propinquus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244
<i>Cadulus subfusiformis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
<i>Calliostoma occidentale</i>	0	0	0	0	0	24	0	0	0	0	0	0	0	0	19
<i>Calycella syringa</i>	0	0	0	0	14	3	0	0	0	0	0	0	0	0	0
<i>Campanularia volubilis</i>	0	12	0	0	14	6	0	0	0	0	0	0	0	0	0
<i>Capulus ungaricus</i>	0	0	0	0	0	0	0	0	13	0	0	0	0	0	15
<i>Cardiomya cadiziana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Ceramaster granularis</i>	0	0	0	0	0	0	0	0	0	5	18	2	0	0	29
<i>Cerastoderma edule</i>	0	0	0	0	0	12	0	0	16	0	0	0	0	0	0
<i>Cerithiella metula</i>	0	0	0	0	0	0	0	0	14	0	0	16	0	1	40
<i>Chaetoderma nitidulum</i>	0	0	0	0	0	0	0	2	13	0	0	0	0	0	0
<i>Chamelea striatula</i>	0	0	0	0	0	26	0	0	0	0	0	11	0	0	14
<i>Cladorhiza gelida</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Clausilia bidentata</i>	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
<i>Clelandella miliaris</i>	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0
<i>Clione limacina</i>	0	0	0	12	17	10	8	6	59	0	9	168	0	2	163
<i>Colus gracilis</i>	0	0	0	0	0	23	0	0	14	0	0	12	0	0	22
<i>Coryphella verrucosa</i>	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
<i>Crenella decussata</i>	0	0	0	0	0	0	0	0	58	0	10	63	0	8	102
<i>Crossaster papposus</i>	1	14	72	30	9	38	0	0	0	0	0	0	0	5	18
<i>Ctenodiscus crispatus</i>	0	0	0	0	0	0	0	0	0	5	18	5	0	2	23
<i>Curtitoma trevelliiana</i>	0	0	0	0	0	0	0	0	40	5	19	17	0	0	0
<i>Curtitoma violacea</i>	0	0	0	0	0	0	0	0	11	0	3	10	0	0	0
<i>Cuspidaria lamellosa</i>	0	0	0	0	0	0	0	0	14	0	0	113	0	0	760
<i>Cuspidaria obesa</i>	0	0	0	0	0	0	0	0	0	0	0	46	0	4	155
<i>Cuspidaria subtorta</i>	0	0	0	0	12	0	0	0	0	5	26	5	0	6	27
<i>Cyanea capillata</i>	0	0	0	0	0	0	0	0	0	0	0	280	0	0	24
<i>Cyclopecten haskynsi</i>	0	5	21	16	38	29	4	1	25	5	18	45	0	0	556
<i>Cyllista splendens</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Cyrtillia aequalis</i>	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0
<i>Cyrtillia linearis</i>	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
<i>Dacrydium ockelmanni</i>	0	0	0	0	0	0	0	0	0	0	0	103	0	0	893
<i>Dacrydium vitreum</i>	2	24	50	44	104	68	5	22	66	5	21	54	0	14	635
<i>Delectopecten vitreus</i>	0	0	0	0	0	21	0	0	11	0	0	32	0	0	153
<i>Dendrodoa aggregata</i>	0	0	0	0	0	0	0	7	12	0	0	0	0	0	0
<i>Dendrodoa grossularia</i>	0	0	0	0	0	0	0	13	3	0	0	0	0	0	0
<i>Dendronotus frondosus</i>	0	0	0	0	3	25	0	0	0	0	20	0	0	6	8
<i>Desmophyllum pertusum</i>	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0
<i>Diaphana hiemalis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1
<i>Didemnum albidum</i>	0	0	0	0	0	0	0	5	7	0	0	0	0	0	0
<i>Dimophyes arctica</i>	0	0	0	6	3	10	0	0	0	0	0	0	0	0	0
<i>Diplodonta torelli</i>	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Doto coronata</i>	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Echinocardium flavescens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
<i>Echinocyamus pusillus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
<i>Echinus esculentus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	131	3
<i>Elpidia belyaevi</i>	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
<i>Elpidia glacialis</i>	0	0	0	0	0	0	0	0	0	7	18	5	0	0	24
<i>Emarginula crassa</i>	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
<i>Ennucula convexa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
<i>Ennucula corticata</i>	0	0	0	0	0	0	0	0	23	0	2	28	0	2	118
<i>Ennucula tenuis</i>	3	45	3	0	42	14	0	7	51	0	62	51	0	45	123
<i>Entalina tetragona</i>	0	0	0	0	0	0	0	0	0	0	0	18	0	0	69
<i>Epizaanthus papillosus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	65
<i>Erginus rubellus</i>	1	9	3	0	0	0	0	0	0	0	11	3	0	0	0
<i>Euconulus fulvus</i>	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0
<i>Eudendrium capillare</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Eudendrium ramosum</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Eulima bilineata</i>	0	0	0	0	0	0	0	0	14	0	0	15	0	0	35
<i>Eulimella scillae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
<i>Eumetula arctica</i>	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
<i>Eupyrus scaber</i>	0	0	0	0	0	0	0	0	0	6	23	3	0	0	0
<i>Euspira montagui</i>	0	0	0	0	0	0	0	0	71	0	0	50	0	0	168
<i>Euspira nitida</i>	0	0	0	0	0	0	0	20	0	0	0	0	0	0	26
<i>Flabellum macandrewi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
<i>Frigidoalvania janmayeni</i>	0	0	0	0	0	0	0	0	0	5	27	1	0	0	0
<i>Galba truncatula</i>	0	0	19	0	0	0	0	0	25	0	0	0	0	0	0
<i>Genaxinus eumyrius</i>	0	0	0	0	0	0	0	0	0	0	0	15	0	0	72
<i>Glandulactis spetsbergensis</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Golfingia margaritacea</i>	0	0	0	0	0	0	0	0	0	0	15	31	0	25	7
<i>Golfingia vulgaris</i>	0	0	0	0	0	0	0	0	0	0	36	56	0	51	0
<i>Gorgonocephalus arcticus</i>	0	0	0	22	19	8	0	0	0	0	0	0	0	0	0
<i>Gorgonocephalus eucnemis</i>	0	8	6	31	14	11	6	10	0	0	0	0	0	0	0
<i>Gracilechinus acutus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
<i>Grammaria abietina</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Gyraulus acronicus</i>	0	0	29	0	0	24	0	0	59	0	0	13	0	0	0
<i>Gyrodactylus albalacustris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
<i>Gyrodactylus arcuatus</i>	0	0	0	0	0	0	0	0	0	0	0	16	0	0	55
<i>Halcampa arctica</i>	6	13	2	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Halecium beanii</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Halecium labrosum</i>	0	12	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Haliella stenostoma</i>	0	0	0	0	0	21	0	0	0	0	0	23	0	0	64
<i>Halitholus yoldiaearticae</i>	0	0	0	0	0	0	0	0	0	0	0	30	0	0	24
<i>Halocynthia pyriformis</i>	0	0	0	0	0	0	0	14	3	0	0	0	0	138	0
<i>Hanleya hanleyi</i>	0	0	0	0	0	21	0	0	44	0	0	14	0	0	24
<i>Henricia perforata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	44
<i>Henricia sanguinolenta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56
<i>Hermania scabra</i>	0	0	0	0	0	0	0	0	12	0	0	18	0	0	12
<i>Heteronomia squamula</i>	0	0	0	0	8	56	0	0	12	0	0	33	0	0	429
<i>Hiatella rugosa</i>	0	0	0	0	0	0	0	0	0	7	11	11	0	5	17
<i>Hippasteria phrygiana</i>	0	0	0	0	0	0	0	0	0	5	18	3	0	1	10
<i>Hormathia digitata</i>	0	0	0	0	1	23	0	19	20	5	18	1	0	0	0
<i>Hormathia nadosa</i>	0	17	1	0	0	0	0	0	0	5	18	1	0	0	0
<i>Hydractinia carica</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Hydrallmania falcata</i>	0	0	0	0	6	7	0	0	0	0	0	0	0	0	0
<i>Iothia fulva</i>	0	0	0	0	0	27	0	0	35	0	0	18	0	0	17
<i>Isohypsiobius prosostomus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
<i>Kadosactis rosea</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Karnekampia sulcata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159
<i>Kellia suborbicularis</i>	0	0	0	0	0	0	0	0	19	0	0	11	0	0	0
<i>Kelliella miliaris</i>	0	0	0	0	0	0	0	0	12	0	0	18	0	0	82
<i>Kophobelemon stelliferum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
<i>Korethraster hispidus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Kurtiella bidentata</i>	0	0	0	0	0	0	0	0	0	0	0	11	0	0	24
<i>Labidoplax buskii</i>	0	0	0	0	0	0	0	0	0	0	0	51	0	0	1144
<i>Lacuna crassior</i>	0	0	0	0	0	0	0	0	0	7	7	7	0	0	0
<i>Lacuna pallidula</i>	0	0	0	0	1	40	0	0	0	0	1	18	0	0	0
<i>Lacuna parva</i>	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0
<i>Lacuna vincta</i>	0	3	10	0	0	72	0	0	88	0	0	56	0	0	25
<i>Laeocochlis sinistrata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
<i>Lafoea dumosa</i>	3	11	2	6	7	13	0	44	3	5	18	1	0	0	0
<i>Laona quadrata</i>	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
<i>Ledella messanensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
<i>Lepeta caeca</i>	2	30	9	0	19	135	0	7	81	0	29	40	0	91	47
<i>Lepidochitona cinerea</i>	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Leptaxinus minutus</i>	0	0	0	0	0	0	0	0	0	0	0	17	0	0	199
<i>Leptochiton alveolus</i>	0	0	0	0	0	13	0	0	45	0	0	42	0	0	32
<i>Leptochiton arcticus</i>	0	0	12	1	9	61	0	13	46	0	0	0	0	0	16
<i>Leptochiton asellus</i>	0	0	0	0	1	35	0	0	118	0	0	44	0	1	46
<i>Leptychaster arcticus</i>	0	0	0	0	0	0	0	0	0	5	18	4	0	0	49
<i>Limacina helicina</i>	0	0	0	19	25	1	16	9	14	0	32	95	0	0	156
<i>Limacina retroversa</i>	0	0	0	0	0	50	0	0	0	0	0	0	0	1	19
<i>Limatula gwyni</i>	0	0	0	0	0	0	0	0	0	0	0	18	0	0	269
<i>Limatula subauriculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
<i>Limea crassa</i>	0	0	0	0	0	0	0	0	0	0	0	22	0	0	125
<i>Limopsis aurita</i>	0	0	0	0	0	0	0	0	0	0	0	59	0	0	34
<i>Limopsis cristata</i>	0	0	0	0	0	0	0	0	0	0	0	60	0	0	541
<i>Limopsis minuta</i>	0	0	0	0	0	0	0	0	0	0	0	75	0	0	133
<i>Liocyma fluctuosa</i>	11	37	2	26	29	3	0	0	0	0	13	0	0	0	0
<i>Littorina littorea</i>	0	0	0	0	0	120	0	0	0	0	0	16	0	0	25
<i>Littorina obtusata</i>	0	0	14	0	0	248	0	0	13	0	0	27	0	0	33
<i>Littorina saxatilis</i>	0	5	30	0	3	257	0	0	25	0	2	35	0	6	46
<i>Lophaster furcifer</i>	1	13	3	15	15	1	0	0	0	5	18	1	0	0	0
<i>Lucinoma borealis</i>	0	0	0	0	0	14	0	0	0	0	0	17	0	0	15
<i>Luidia sarsii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
<i>Lyonsia arenosa</i>	1	30	20	19	24	36	0	0	0	0	0	0	0	0	0
<i>Lyonsiella abyssicola</i>	0	0	0	0	0	0	0	0	0	0	0	41	0	2	602
<i>Macoma balthica</i>	0	0	0	0	0	38	0	0	0	1	0	23	0	0	16
<i>Macoma moesta</i>	3	33	0	0	15	0	0	0	0	0	0	0	0	0	0
<i>Macrobrotus richtersi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
<i>Madrepora oculata</i>	0	0	0	0	0	123	0	0	0	0	0	0	0	0	0
<i>Mancikella divae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31
<i>Margarites helacinus</i>	0	0	0	2	5	130	0	0	39	0	18	26	0	5	22
<i>Margarites olivaceus</i>	0	10	3	0	2	9	0	0	0	0	35	3	0	27	6
<i>Margaritifera margaritifera</i>	0	0	0	0	0	0	0	0	30	0	0	35	0	0	0
<i>Mendicula ferruginosa</i>	0	0	0	0	0	0	0	0	26	0	4	28	0	0	221
<i>Mendicula pygmaea</i>	0	0	0	0	0	0	0	0	0	0	0	73	0	0	46
<i>Metzgeria alba</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
<i>Madeeria rotunda</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Modiolula phaseolina</i>	0	0	0	0	0	0	0	0	48	0	0	42	0	0	213
<i>Moelleria costulata</i>	0	0	0	0	0	0	0	0	18	0	9	16	0	4	7

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Mahnia mohni</i>	0	0	0	0	0	0	0	0	0	0	1	11	0	0	14
<i>Mahnia parva</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Mantacuta substriata</i>	0	0	0	0	0	0	0	0	0	0	0	11	0	0	26
<i>Musculus discors</i>	0	0	0	4	1	40	0	0	12	0	15	18	0	7	27
<i>Musculus niger</i>	0	26	8	2	11	6	0	1	30	7	25	37	0	6	39
<i>Mya arenaria</i>	0	0	0	0	0	14	0	0	0	0	0	0	0	0	12
<i>Myriotrachus rinkii</i>	0	0	0	0	0	0	0	0	0	7	18	1	0	0	0
<i>Myriotrachus theeli</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
<i>Myriotrachus vitreus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
<i>Mytilus edulis</i>	0	0	0	2	0	136	0	0	11	0	1	890	1	0	191
<i>Nephasoma liljeborgii</i>	0	0	0	0	0	0	0	0	0	0	19	0	0	23	0
<i>Neptunea antiqua</i>	0	17	4	0	9	3	0	3	14	0	0	0	0	0	0
<i>Nucella lapillus</i>	0	1	14	0	0	177	0	0	16	0	0	748	0	0	80
<i>Nucula nucleus</i>	0	0	0	0	0	0	0	0	19	0	0	0	0	0	34
<i>Nucula tumidula</i>	0	0	0	0	0	0	0	0	12	0	0	57	0	0	198
<i>Nuculana minuta</i>	0	12	6	0	0	12	0	0	31	0	0	25	0	6	46
<i>Obelia dichotoma</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	77	0
<i>Obelia longissima</i>	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0
<i>Odostomia unidentata</i>	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0
<i>Oenopota cinerea</i>	0	0	0	0	0	0	0	0	0	5	18	2	0	0	0
<i>Oenopota elegans</i>	0	0	0	0	0	0	0	0	22	0	4	12	0	0	0
<i>Oenopota pyramidalis</i>	0	0	0	0	0	0	0	0	0	5	20	3	0	0	0
<i>Oenopota tenuicostata</i>	0	0	0	0	0	0	0	0	20	0	0	22	0	1	29
<i>Onchidoris muricata</i>	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
<i>Onchnesoma squamatum</i>	0	0	0	0	0	0	0	0	0	0	0	91	0	0	237
<i>Onchnesoma steenstrupii</i>	0	0	0	0	0	0	0	0	0	0	0	58	0	0	168
<i>Onoba aculeus</i>	0	0	0	0	0	120	0	0	0	0	1	16	0	0	11
<i>Onoba semicostata</i>	0	0	0	0	0	0	0	0	28	0	0	19	0	0	0
<i>Ophiacantha abyssicola</i>	0	0	0	0	0	13	0	0	0	0	0	48	0	0	142
<i>Ophiacantha bidentata</i>	11	86	323	295	185	153	13	61	4	38	18	3	0	41	137
<i>Ophiactis abyssicola</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
<i>Ophiacten affinis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1131
<i>Ophiacten gracilis</i>	0	0	0	0	0	0	0	0	0	0	0	17	0	0	136
<i>Ophiacten sericeum</i>	4	71	62	238	125	56	22	44	2	38	18	3	0	21	77
<i>Ophiolycus purpureus</i>	0	0	0	0	0	13	0	0	0	0	0	0	0	0	27
<i>Ophiopholis aculeata</i>	6	61	351	117	90	237	0	36	12	5	18	30	0	12	251

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Ophiopleura borealis</i>	0	0	0	85	18	0	24	24	0	5	18	1	0	2	34
<i>Ophiopus arcticus</i>	0	0	0	20	22	0	3	7	3	17	18	1	0	0	24
<i>Ophiocolex glacialis</i>	2	24	59	56	56	26	8	13	5	7	18	4	0	1	56
<i>Ophiura albida</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
<i>Ophiura carnea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
<i>Ophiura robusta</i>	6	40	201	209	75	136	15	15	3	41	24	1	0	10	248
<i>Palliolium striatum</i>	0	0	0	0	0	0	0	0	16	0	0	0	0	0	18
<i>Palliolium tigrinum</i>	0	0	0	0	0	0	0	0	11	0	0	0	0	0	11
<i>Pandora glacialis</i>	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Papillicardium minimum</i>	0	0	0	0	0	0	0	0	40	0	0	61	0	1	1112
<i>Paracuraria adunca</i>	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
<i>Paragorgia arborea</i>	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
<i>Parastichopus tremulus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46
<i>Parathyasira dunbari</i>	0	0	0	0	0	0	0	0	0	17	21	0	33	227	
<i>Parathyasira equalis</i>	2	10	35	24	46	49	3	36	0	4	61	0	0	0	279
<i>Parathyasira granulosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
<i>Parvicardium pinnulatum</i>	0	0	0	0	0	0	0	0	44	0	0	41	0	0	85
<i>Patella pellucida</i>	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
<i>Patella vulgata</i>	0	0	0	0	0	24	0	0	0	0	0	0	0	0	18
<i>Pecten maximus</i>	0	0	0	0	0	0	0	0	0	0	0	138	0	0	0
<i>Peregrina peregra</i>	0	0	19	0	0	21	0	0	133	0	0	17	0	0	12
<i>Phakellia ventilabrum</i>	0	0	0	0	0	0	0	0	0	0	0	0	131	2	2
<i>Phascalion strombus</i>	0	0	0	0	0	0	0	0	0	5	29	19	0	17	143
<i>Plehnia arctica</i>	0	81	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pleurobrachia pileus</i>	0	0	0	0	0	0	0	0	11	0	0	24	0	0	0
<i>Plicifusus kroyeri</i>	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Platocnide borealis</i>	0	0	0	0	0	0	0	0	38	0	0	78	0	0	93
<i>Pododermus patelliformis</i>	0	0	0	0	0	0	0	0	16	0	0	14	0	0	12
<i>Pollicordia jeffreysi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
<i>Poliometra proluxa</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Polycarpa fibrosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	451
<i>Polymastia mamillaris</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Poromya granulata</i>	0	0	0	0	0	0	0	0	0	0	0	15	0	0	129
<i>Portlandia arctica</i>	0	0	0	0	21	0	0	0	0	0	10	2	0	9	6
<i>Praephillina finmarchica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20
<i>Priapulopsis bicaudatus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Primnoa resedaeformis</i>	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0
<i>Propobela exarata</i>	0	0	0	0	0	0	0	0	0	0	5	7	0	0	0
<i>Propobela harpularia</i>	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
<i>Pseudarchaster parelii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
<i>Pteraster militaris</i>	0	8	18	13	10	19	0	0	0	0	0	0	0	1	12
<i>Ptychogasteria polaris</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Ptychogasteria crocea</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Pulsellum affine</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68
<i>Pulsellum lofatense</i>	0	0	0	0	0	0	0	0	13	0	0	0	0	0	25
<i>Punctulum wyvillethamsoni</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	41
<i>Puncturella noachina</i>	2	21	12	0	3	125	0	0	90	0	7	39	0	4	90
<i>Pusillina inconspicua</i>	0	0	0	0	0	0	0	0	18	0	0	17	0	0	0
<i>Pycnanthus densus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Radiella sol</i>	0	0	0	0	0	0	0	0	0	5	18	3	0	0	0
<i>Retifusus latericeus</i>	0	0	0	0	0	0	0	0	0	5	18	2	0	0	0
<i>Rhizocaulus verticillatus</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Rhizocrinus lofatensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
<i>Rissoa parva</i>	0	0	0	0	0	16	0	0	20	0	0	11	0	0	0
<i>Sarsia tubulosa</i>	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0
<i>Scaphander lignarius</i>	0	0	0	0	0	0	0	0	14	0	0	15	0	0	16
<i>Scaphander punctostriatus</i>	0	0	0	0	0	34	0	0	24	0	0	11	0	1	53
<i>Serripes groenlandicus</i>	7	46	25	28	41	35	9	5	4	0	14	4	0	9	5
<i>Sertularella tenella</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Sertularia tenera</i>	4	9	2	0	0	0	0	0	0	5	18	1	0	0	0
<i>Similipecten similis</i>	0	0	0	0	0	0	0	0	35	0	0	20	0	1	74
<i>Siphonodentalium laubieri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	3	213
<i>Siphonodentalium lobatum</i>	0	0	0	0	0	0	0	0	0	5	22	71	0	5	145
<i>Skenea basistriata</i>	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0
<i>Skeneopsis planorbis</i>	0	0	0	0	0	81	0	0	0	0	0	38	0	0	17
<i>Solariella obscura</i>	0	0	0	0	0	16	0	0	0	0	2	15	0	5	16
<i>Spatangus purpureus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
<i>Spatangus raschi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
<i>Spiratropis monterosatoi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
<i>Spisula elliptica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
<i>Stagnicola palustris</i>	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0
<i>Staurostoma mertensii</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Stegophiura nodosa</i>	36	35	98	103	32	134	0	0	0	0	0	0	0	0	0
<i>Stenosemus albus</i>	0	0	0	1	6	106	6	70	123	0	18	65	0	17	30
<i>Steromphala cineraria</i>	0	0	0	0	0	122	0	0	37	0	0	14	0	0	25
<i>Steromphala tumida</i>	0	0	0	0	0	54	0	1	63	0	0	34	0	0	28
<i>Symplectoscyphus tricuspidatus</i>	1	16	2	0	2	9	0	0	0	0	0	0	0	0	0
<i>Synoicum turgens</i>	0	0	0	0	0	0	0	11	12	0	0	0	0	0	0
<i>Tachyrhynchus erosus</i>	0	0	0	0	0	0	0	0	0	5	20	1	0	0	0
<i>Tachyrhynchus reticulatus</i>	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Taranis moerchii</i>	0	0	0	0	0	0	0	0	15	0	0	16	0	0	0
<i>Tectura virginea</i>	0	1	10	0	0	110	0	0	57	0	0	22	0	0	25
<i>Tellimya ferruginosa</i>	0	0	0	0	0	0	0	0	0	0	0	11	0	0	26
<i>Testudinalia testudinalis</i>	0	0	19	0	0	210	0	0	39	0	0	57	0	0	21
<i>Thenea abyssorum</i>	0	0	0	0	0	0	0	0	0	2	9	3	0	0	0
<i>Thesbia nana</i>	0	0	0	0	0	0	0	0	29	0	1	11	0	0	14
<i>Thracia devexa</i>	0	6	5	0	0	0	0	0	0	0	0	0	0	0	20
<i>Thracia myopsis</i>	1	35	44	12	64	92	5	8	19	5	32	17	0	2	44
<i>Thyasira flexuosa</i>	0	0	0	0	0	0	0	0	15	0	1	19	0	1	43
<i>Thyasira gouldii</i>	0	0	0	0	0	0	0	1	17	0	16	25	0	7	120
<i>Thyasira obsoleta</i>	0	0	0	0	0	0	0	0	21	0	0	208	0	1	1484
<i>Thyasira sarsii</i>	0	0	0	0	0	0	0	0	0	0	16	27	0	0	40
<i>Timoclea ovata</i>	0	0	0	0	0	17	0	0	20	0	0	16	0	0	45
<i>Tonicella marmorea</i>	0	0	12	1	3	87	0	64	77	0	19	43	0	91	8
<i>Tremaster mirabilis</i>	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
<i>Tritia incrassata</i>	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
<i>Trophonopsis barvicensis</i>	0	0	0	0	0	11	0	0	21	0	0	14	0	0	12
<i>Turrisipho voeringi</i>	0	0	0	0	0	0	0	0	0	5	18	7	0	0	0
<i>Turtonia minuta</i>	0	0	0	0	0	27	0	0	0	0	0	34	0	0	11
<i>Urticina felina</i>	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
<i>Valvata piscinalis</i>	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
<i>Varicorbula gibba</i>	0	0	0	0	0	0	0	0	11	0	0	11	0	0	0
<i>Vitreolina philippi</i>	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0
<i>Vitrina pellucida</i>	0	0	0	0	0	26	0	0	13	0	0	0	0	0	0
<i>Yoldiella annenkovae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32
<i>Yoldiella frigida</i>	2	9	27	0	45	53	0	4	17	0	6	5	0	7	6
<i>Yoldiella intermedia</i>	0	7	43	0	84	240	0	18	49	5	19	44	0	10	23
<i>Yoldiella lenticula</i>	0	8	17	0	75	240	0	7	55	5	30	74	0	8	291

SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
<i>Yoldiella lucida</i>	0	0	0	0	0	0	0	2	33	7	20	129	0	10	888
<i>Yoldiella nana</i>	0	0	0	0	0	0	0	0	38	0	3	93	0	8	848
<i>Yoldiella philippiana</i>	0	0	0	0	0	0	0	0	25	0	0	28	0	0	74
<i>Yoldiella propinqua</i>	0	0	0	0	0	0	0	0	0	0	0	67	0	9	607
<i>Yoldiella solidula</i>	0	0	0	0	13	0	0	0	0	0	14	18	0	20	445
<i>Ziminella salmonacea</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	16	1

# Comparative figures showing occurrences changes during 1900-1950 log linear model results with an offset and without

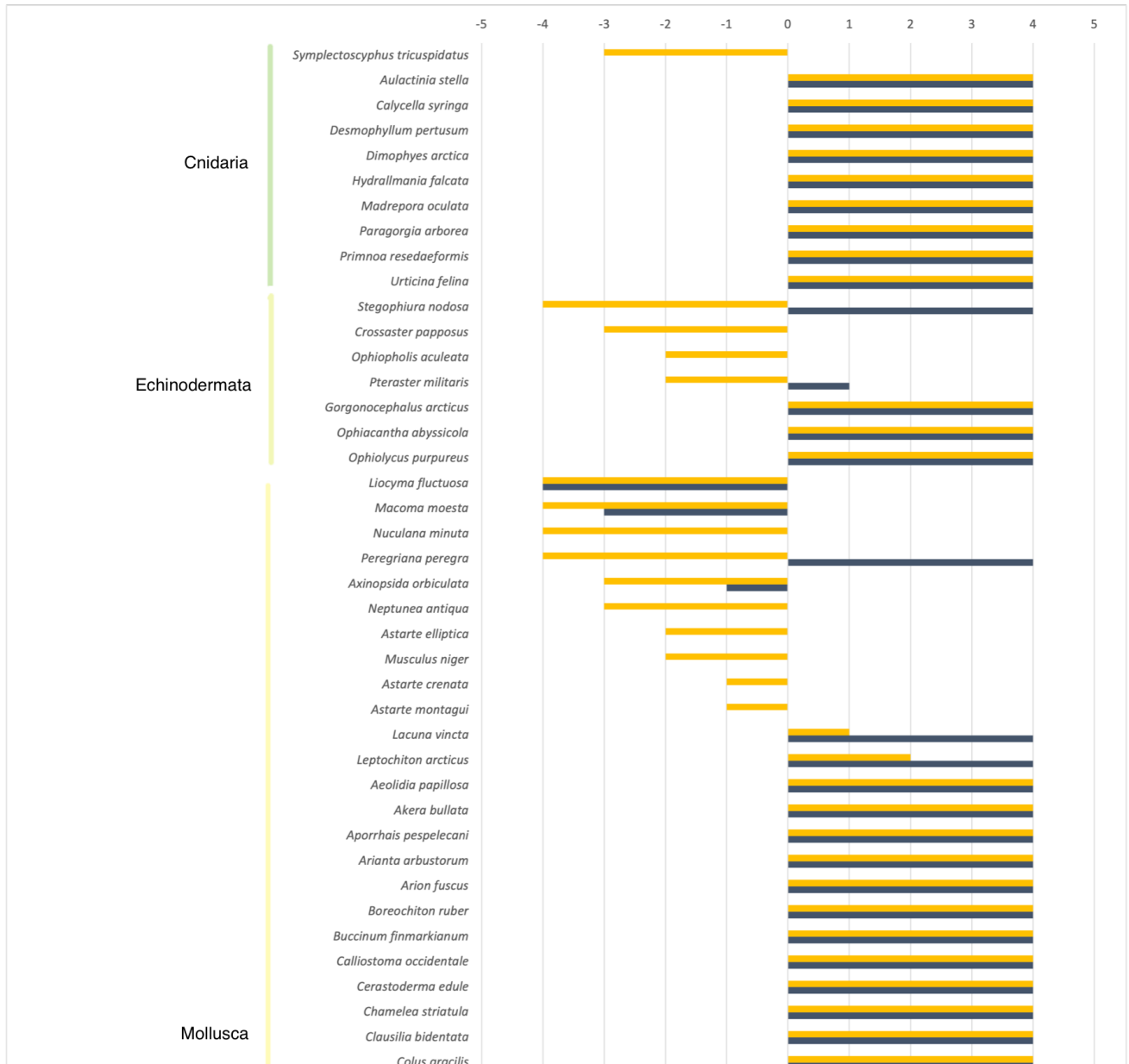
P2: 1900-1950; intercept: P1: before 1900

Species sorted by Phylum.

Significance codes: positive: increase; negative: decrease.

4:  $p < 0.001$ ; 3:  $p < 0.01$ ; 2:  $p < 0.05$ ; 1:  $p < 0.1$

Yellow is with offset, blue is without offset





# Comparative figures showing occurrences changes during 1950-1980 log linear model results with an offset and without

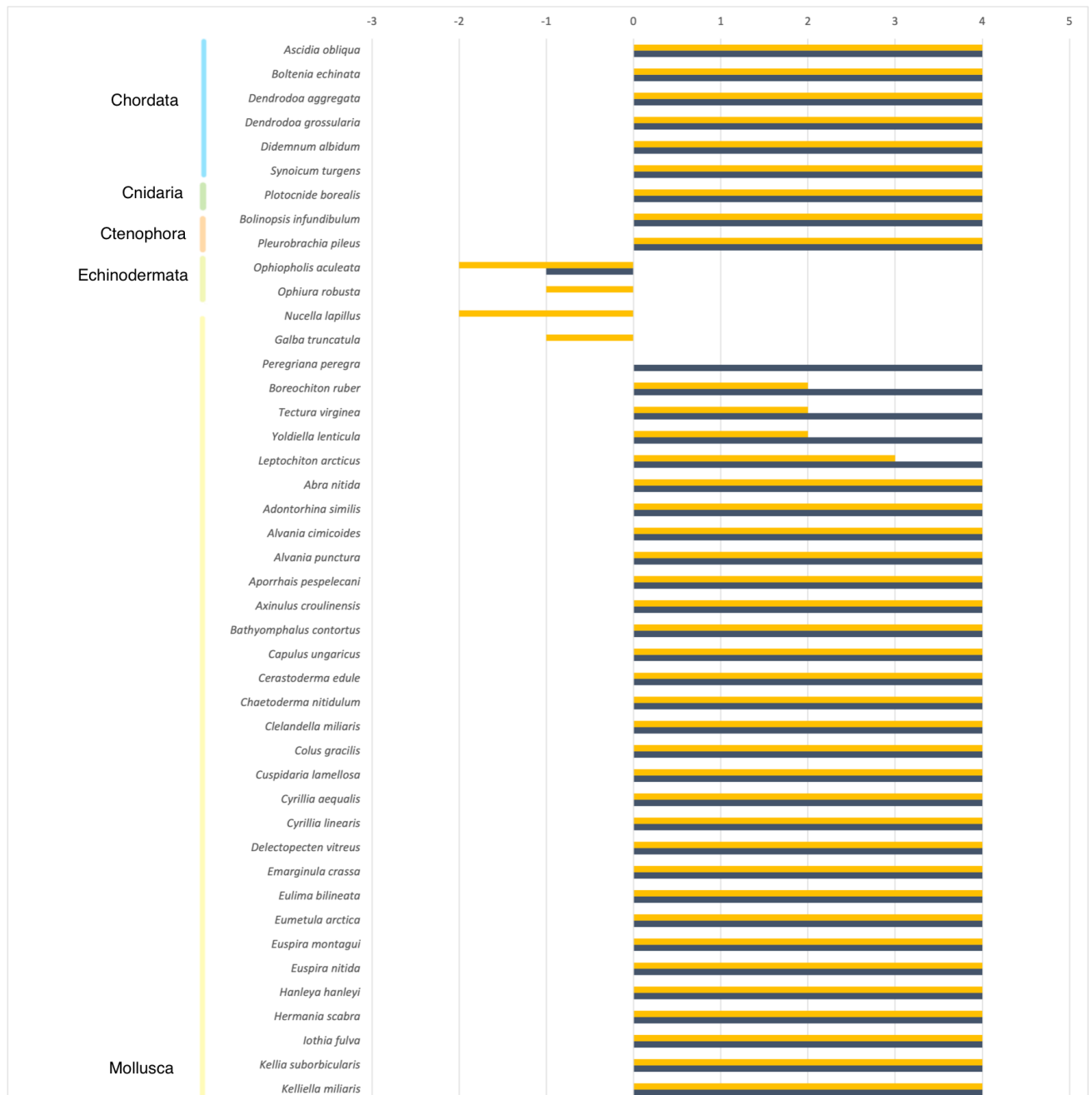
P3: 1950-1980; intercept: P1 before 1900

Species sorted by Phylum.

Significance codes: positive: increase; negative: decrease.

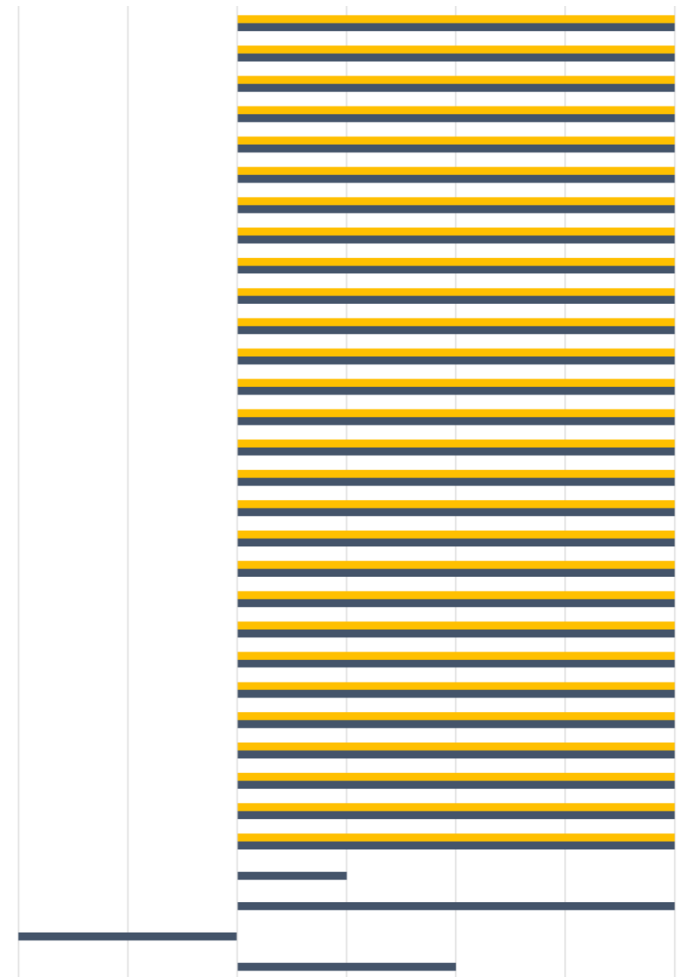
4:  $p < 0.001$ ; 3:  $p < 0.01$ ; 2:  $p < 0.05$ ; 1:  $p < 0.1$

Yellow is with offset, blue is without offset



Mollusca

*Kellia suborbicularis*  
*Kelliella miliaris*  
*Lacuna vincta*  
*Leptochiton alveolus*  
*Margaritifera margaritifera*  
*Modiolula phaseolina*  
*Nucula nucleus*  
*Nucula tumidula*  
*Onoba semicostata*  
*Palliolum striatum*  
*Palliolum tigrinum*  
*Parvicardium pinnulatum*  
*Pododesmus patelliformis*  
*Propebela harpularia*  
*Pulsellum lofotense*  
*Pusillina inconspicua*  
*Rissoa parva*  
*Scaphander lignarius*  
*Skenea basistriata*  
*Steromphala cineraria*  
*Taranis moerchii*  
*Timoclea ovata*  
*Tritia incrassata*  
*Trophonopsis barvicensis*  
*Varicorbula gibba*  
*Vitreolina philippi*  
*Vitrina pellucida*  
*Yoldiella philippiana*  
*Nuculana minuta*  
*Odostomia unidentata*  
*Serripes groenlandicus*  
*Testudinalia testudinalis*



■ With offset P3    ■ Without offset P3

# Comparative figures showing occurrences changes during 1980-2000 log linear model results with an offset and without

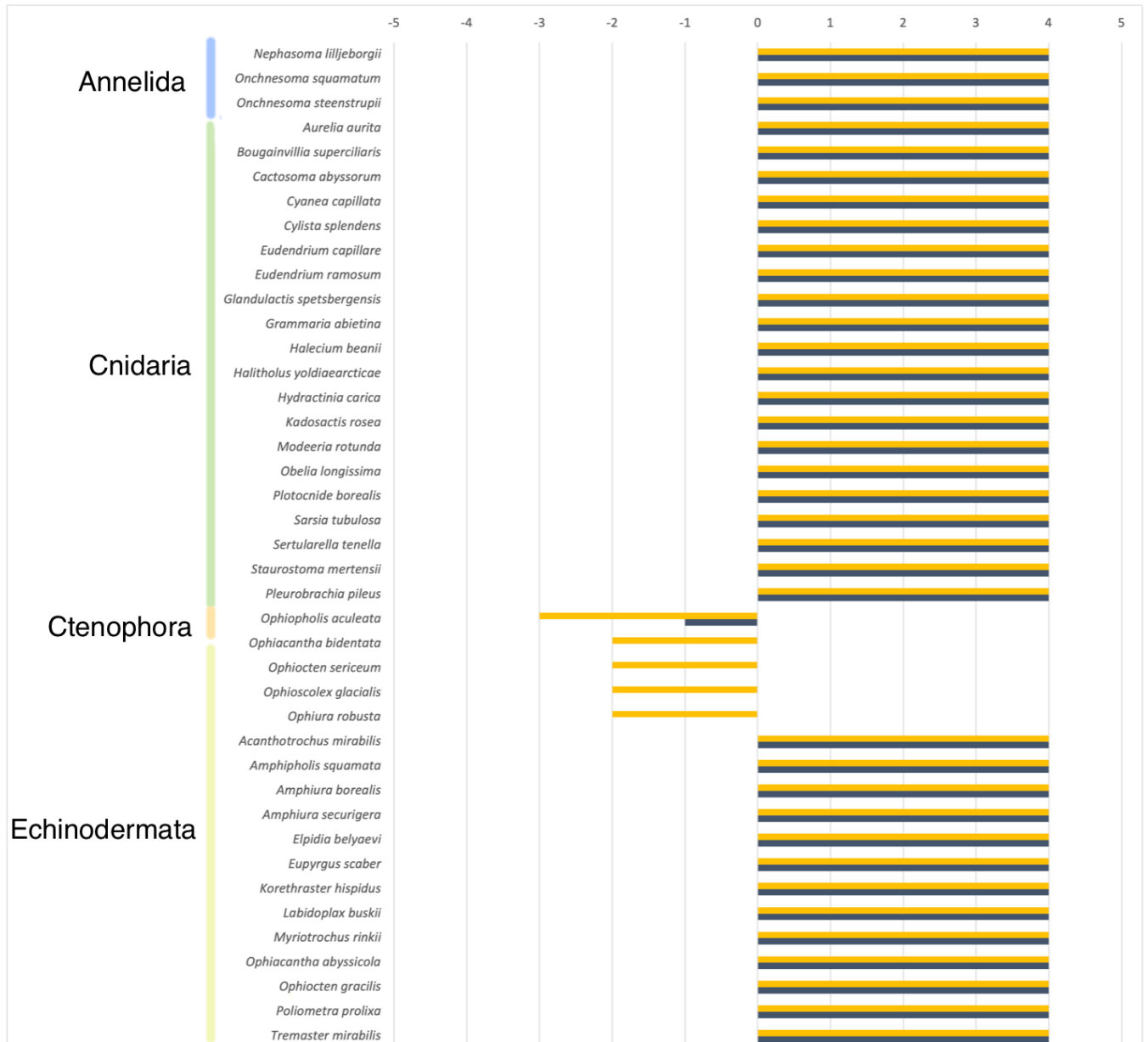
P4: 1980-2000; intercept: P1 before 1900

Species sorted by Phylum.

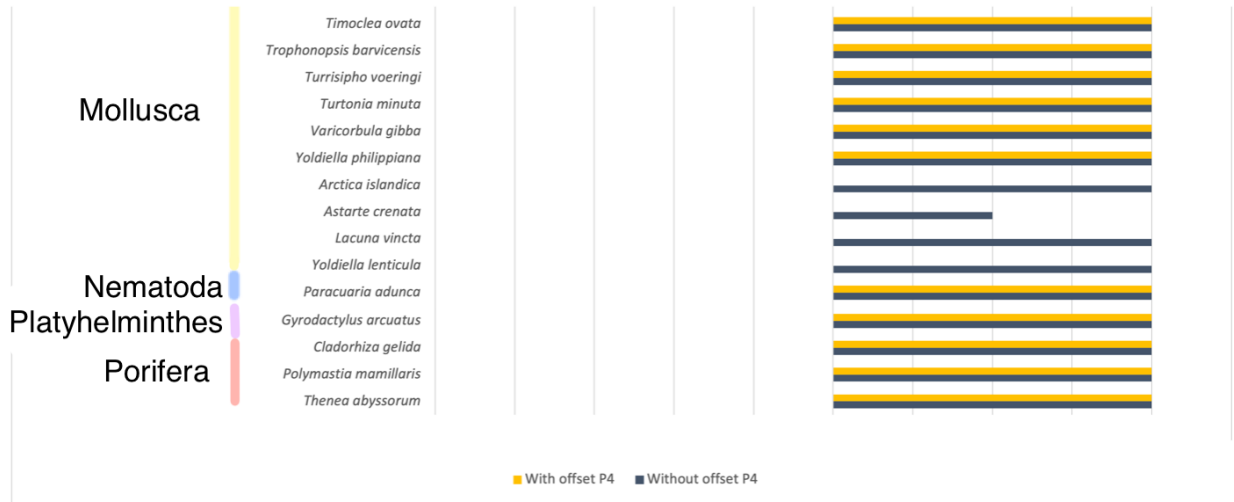
Significance codes: positive: increase; negative: decrease.

4:  $p < 0.001$ ; 3:  $p < 0.01$ ; 2:  $p < 0.05$ ; 1:  $p < 0.1$

Yellow is with offset, blue is without offset







# Comparative figures showing occurrences changes during 2000-2010 log linear model results with an offset and without

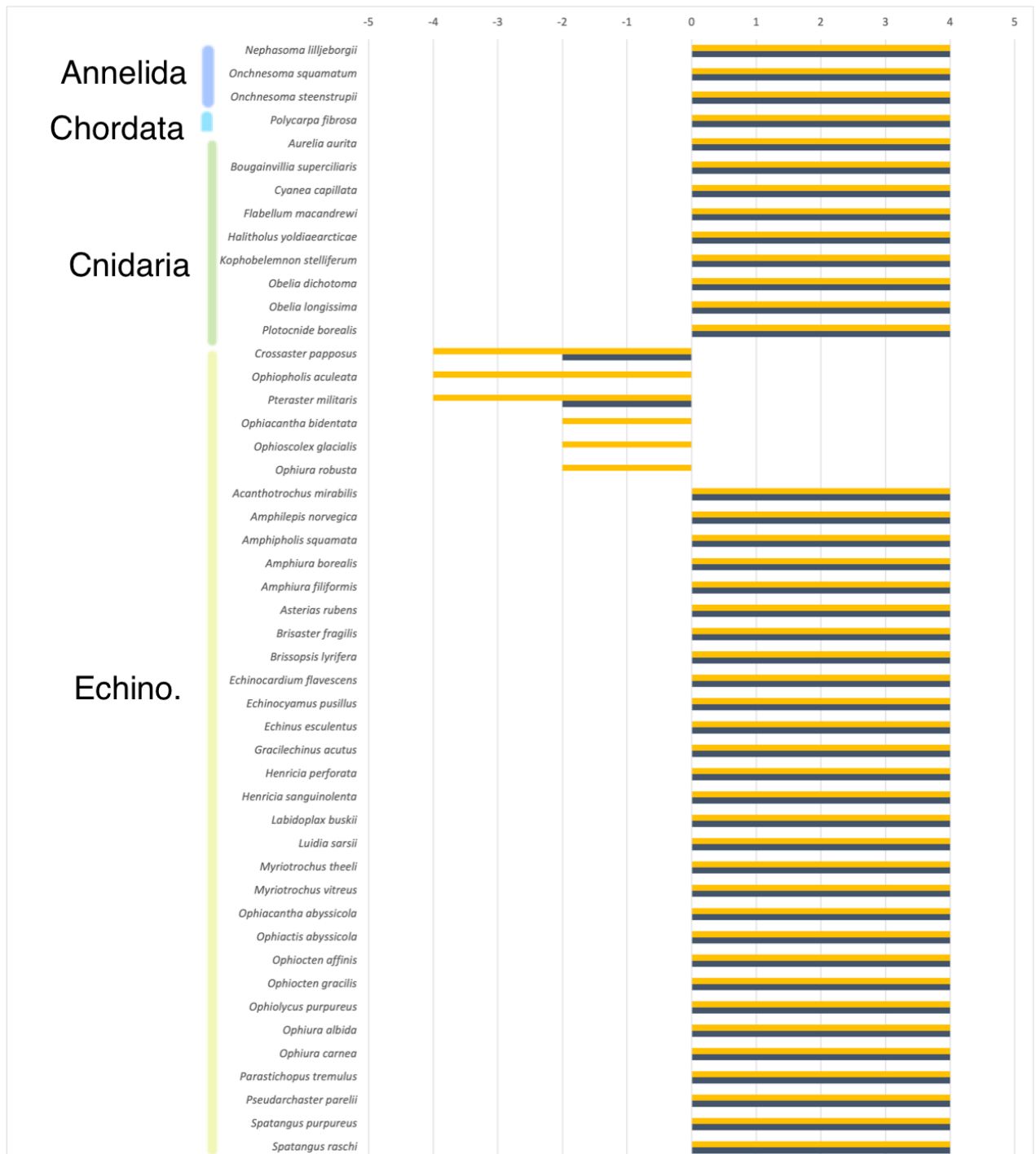
P5: 2000-2010; intercept: P1 before 1900

Species sorted by Phylum.

Significance codes: positive: increase; negative: decrease.

4:  $p < 0.001$ ; 3:  $p < 0.01$ ; 2:  $p < 0.05$ ; 1:  $p < 0.1$

Yellow is with offset, blue is without offset





# Mollusca

- Euspira nitida*
- Genaxinus eumyarius*
- Haliella stenostoma*
- Hanleya hanleyi*
- Hermania scabra*
- Iothia fulva*
- Karnekipia sulcata*
- Kelliella miliaris*
- Kurtiella bidentata*
- Laeocochlis sinistrata*
- Ledella messanensis*
- Leptaxinus minutus*
- Leptochiton alveolus*
- Limatula gwyni*
- Limatula subauriculata*
- Limea crassa*
- Limopsis aurita*
- Limopsis cristata*
- Limopsis minuta*
- Littorina littorea*
- Lucinoma borealis*
- Mancikella divae*
- Mendicula pygmaea*
- Metzgeria alba*
- Modiolula phaseolina*
- Montacuta substriata*
- Mya arenaria*
- Nucula nucleus*
- Nucula tumidula*
- Palliolium striatum*
- Palliolium tigrinum*
- Parathyasira granulosa*
- Parvicardium pinnulatum*
- Patella vulgata*
- Pododesmus patelliformis*
- Policardia jeffreysi*
- Poromya granulata*
- Praeaphiline finmarchica*
- Pulsellum affine*
- Pulsellum lofotense*
- Punctulum wyvillethomsoni*
- Scaphander lignarius*
- Siphonodentalium laubieri*
- Skeneopsis planorbis*
- Spirotropis monterosatoi*
- Spisula elliptica*
- Steromphala cineraria*
- Tellimya ferruginosa*
- Timoclea ovata*
- Trophonopsis barvicensis*
- Turtonia minuta*
- Yoldiella annenkovae*
- Yoldiella philippiana*
- Ziminella salmonacea*
- Astarte crenata*
- Yoldiella lenticula*
- Gyrodactylus albalacustris*
- Gyrodactylus arcuatus*
- Aplysilla sulfurea*
- Phakellia ventilabrum*
- Isohypsibius prosostomus*
- Macrobiotus richtersi*

Plat.  
Porifera  
Tardigrada

■ With offset P5 ■ Without offset P5

