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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 occurences 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).

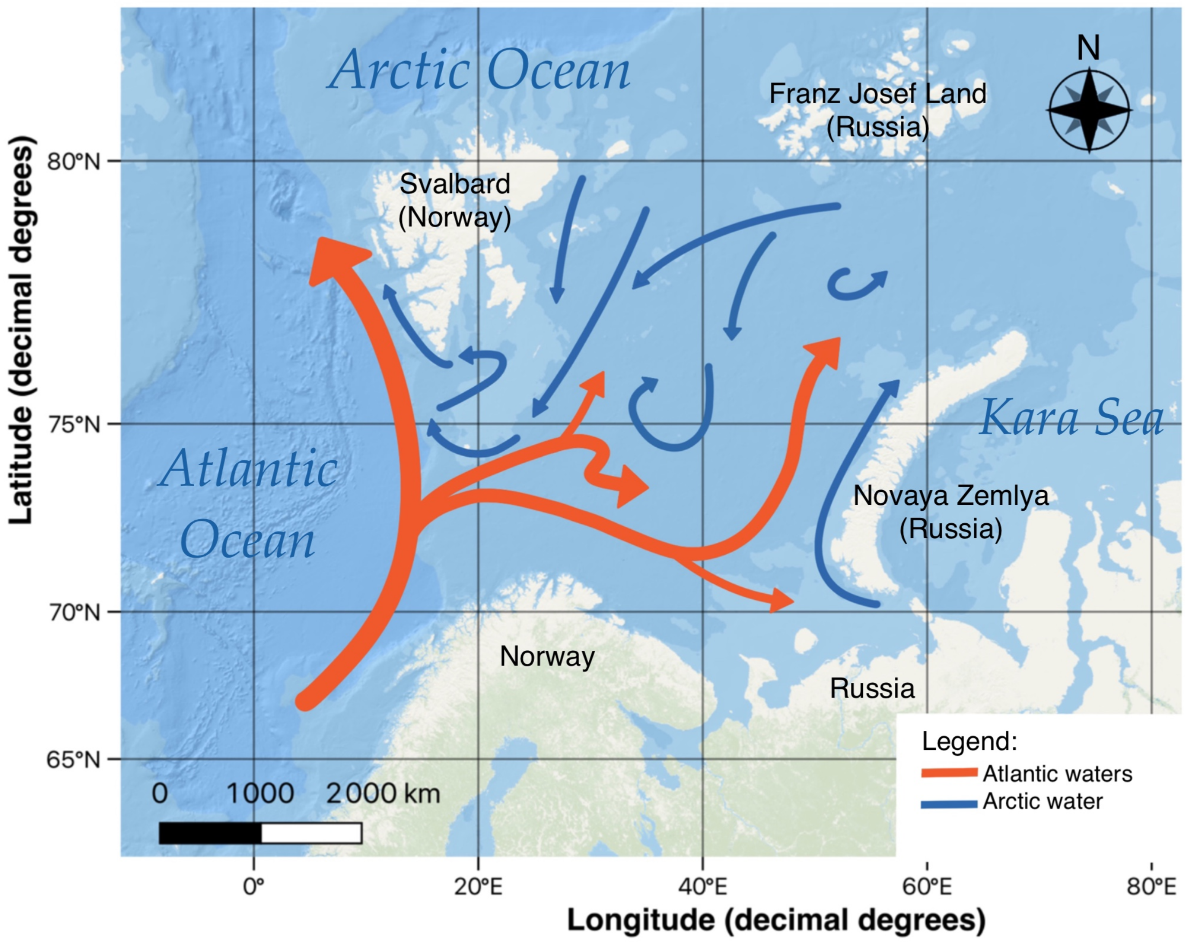


Figure 1: Main input of warm and cold waters into the Barents Sea and its surrounding waters, based on Asplin et al. (2001).

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 ± 0.18°C per decade in the

North and 0.58 ± 0.21°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 21st century. Scientist all around the world were already monitoring our ecosystems back in the 20th 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_2 uptake and a loss of sea ice are also reported (Smedsrud et al., 2022). Increased CO_2 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 ± 0.10m in May and 0.82 ± 0.1m 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 brittles 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^{-2}) 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^2, 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.

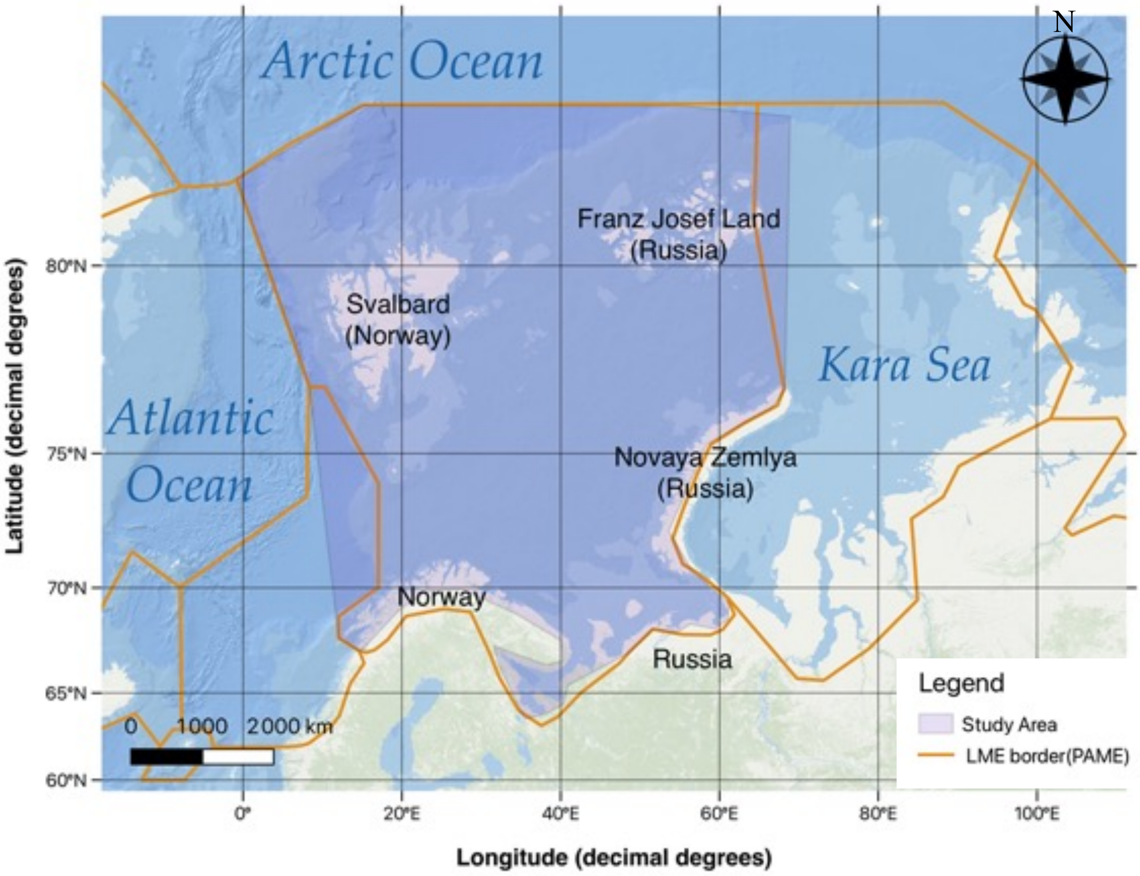


Figure 2: Study Zone in comparison to Protection of the Arctic Marine Environment's (PAME) Large Marine Ecosystems (LME). In purple is the polygon used for this paper, in orange are the border set by PAME's LMEs.

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, Arthopoda were excluded from the dataset.

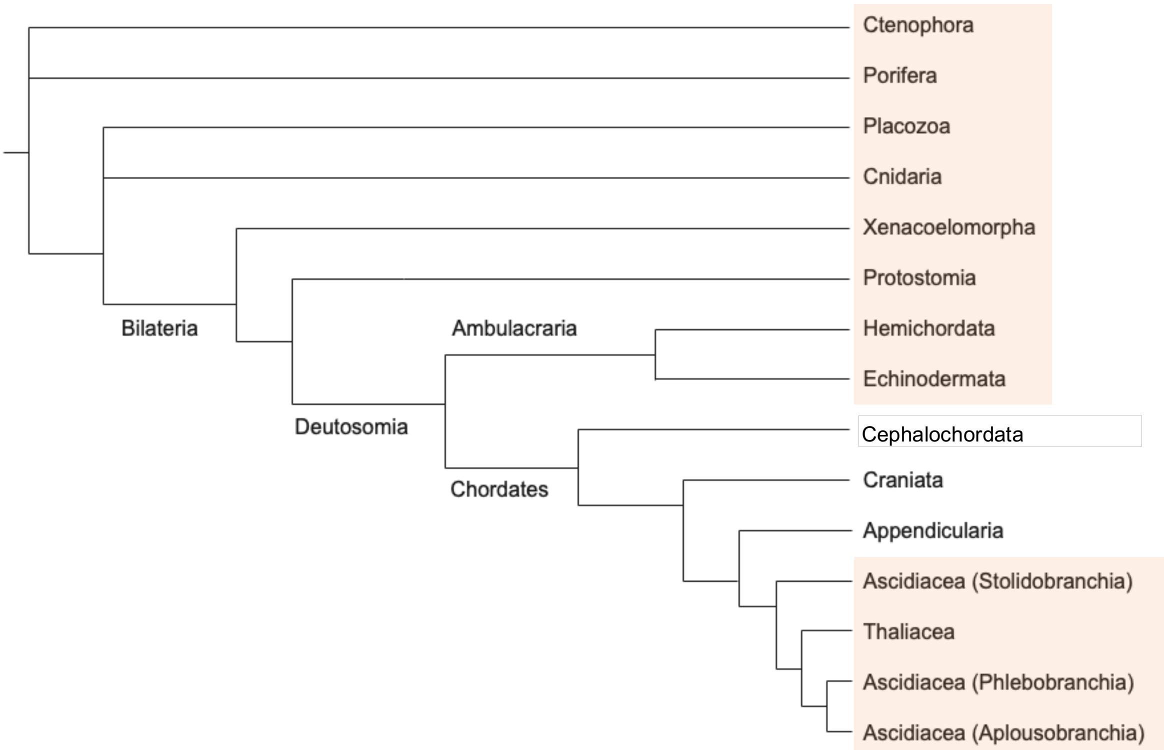


Figure 3: Animal phylogenic tree showing in orange the selected taxa for this study. Built using data extracted from Braun et al. 2020, Franchi at al. 2017 and Giribet and Edgecombe's book "The Invertebrate Tree of Life" (Braun et al., 2020; Franchi & Ballarin, 2017; Giribet & Edgecombe, 2020a, 2020b) 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^2, contains the water with a mean temperature between -2°C and 0°C, i.e. Arctic waters low in salinity, “Z2: mixed”, 675 733km^2, ranges between 0°C to 2°C is a result of the mixing of Arctic and Atlantic waters and “Z3: warm”, 939 795km^2, consists of Atlantic waters, high in salinity with a temperature between 2°C to 4°C (Fig. 4b).

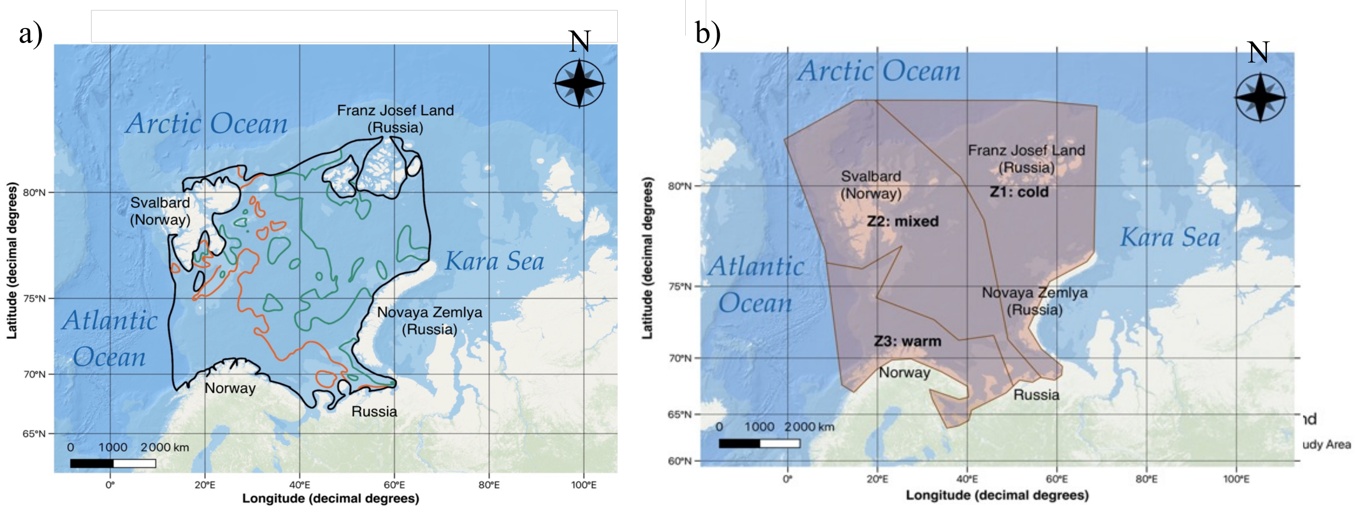


Figure *4*: Map of the Barents Sea including a) mean near-bottom temperature for the periods 2004–2018 from Skagseth et al. (2020). Black outline shows the limits of the study area, orange and green lines represents the temperature limits of 2°C and 0°C respectively; b) study Area separated in three 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).

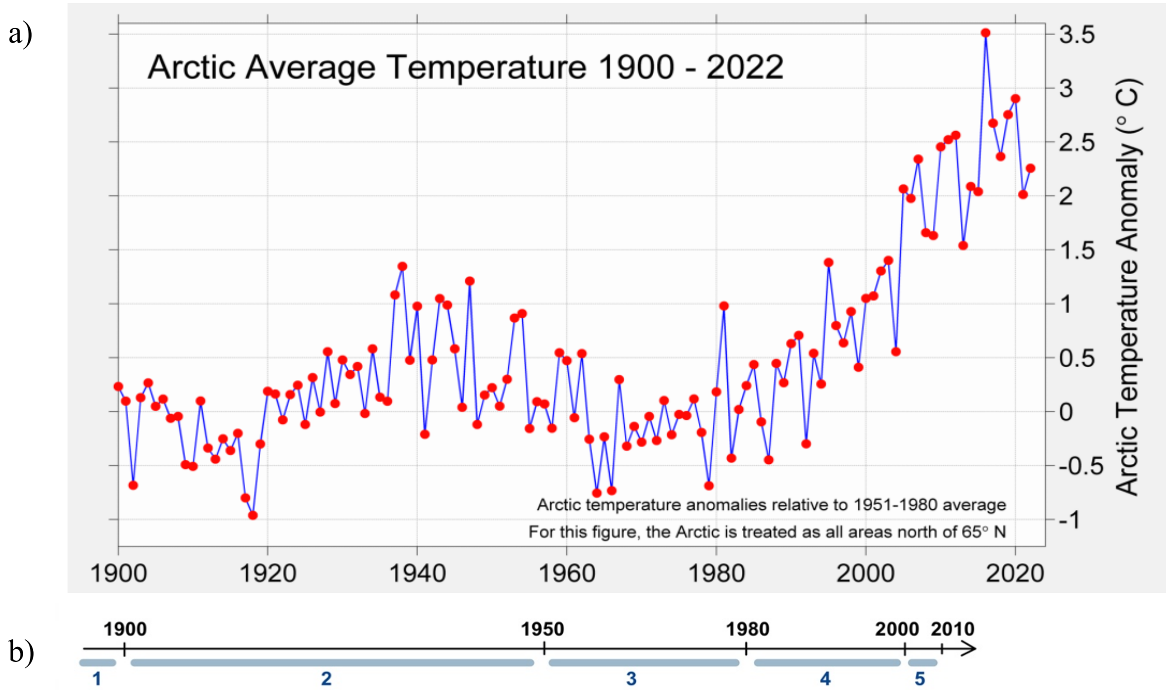


Figure *5*: a) Berkeley Earth's Global Temperature report for 2022, Arctic Average Air Temperature 1900-2022 (https://berkeleyearth.org/global-temperature-report-for-2022/). b) Timeline of the study's period. In blue the five periods used in this study; 1 represent "before 1900".

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, occurences 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 aquire 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 1st March 2023, above 15 000 occurences. The temporal range of observations go from January 1844 (oldest from Norway June 1876) to September 2021 (Altenburger & Bergersen, 2023). Limiting ourselves to occurences 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.

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

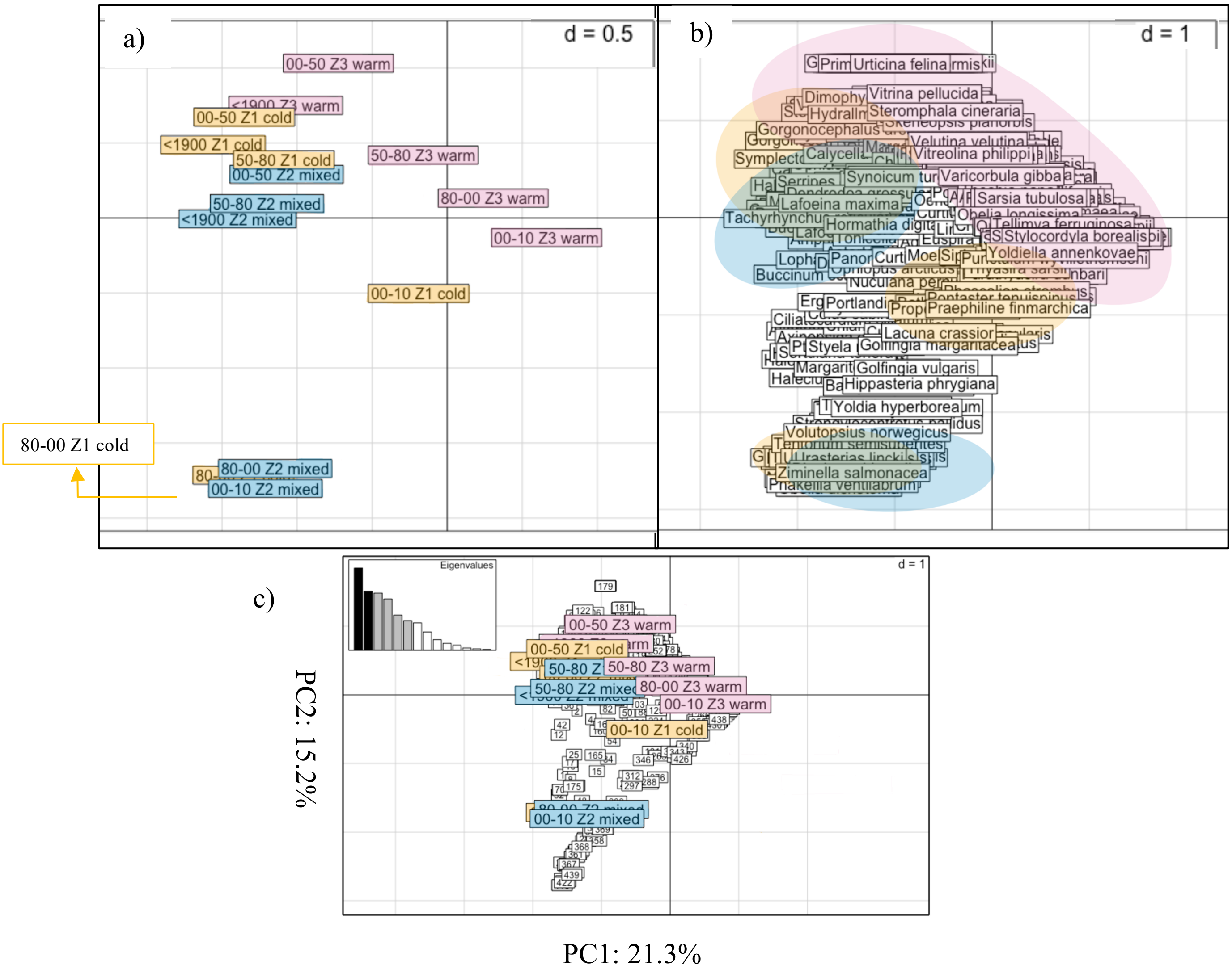


Figure 7: Correspondence Analysis plot of invertebrate occurrence records in the Barents Sea from before 1900 to 2010. Ordination shown by a) the "period · zone" mean distribution, b) species associated with the data period · zone patterns, c) combination of a) and b) with PC1, PC2 and eigenvalues (species 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).

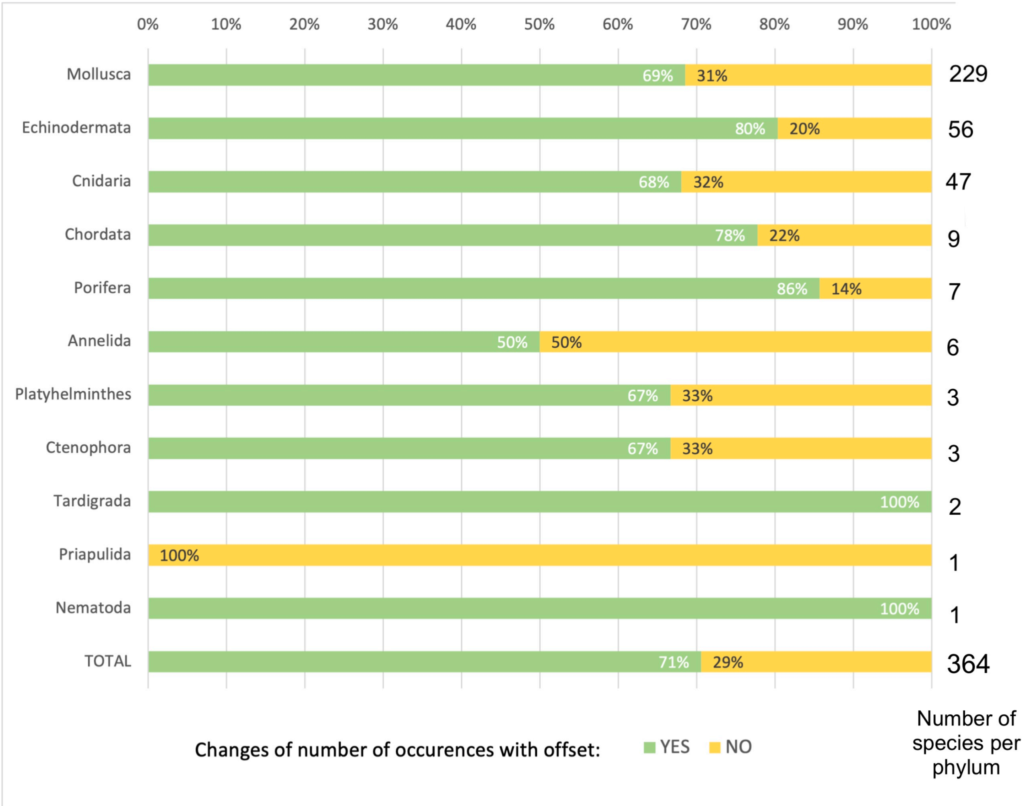


Figure 8: Significant change of occurrence record density in invertebrate species per phylum from before 1900 until 2010 in the Barents Sea (indicated in green). "YES" means species showed a significant change in occurrence in at least one period relative to the reference period; "NO" means that in none 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.

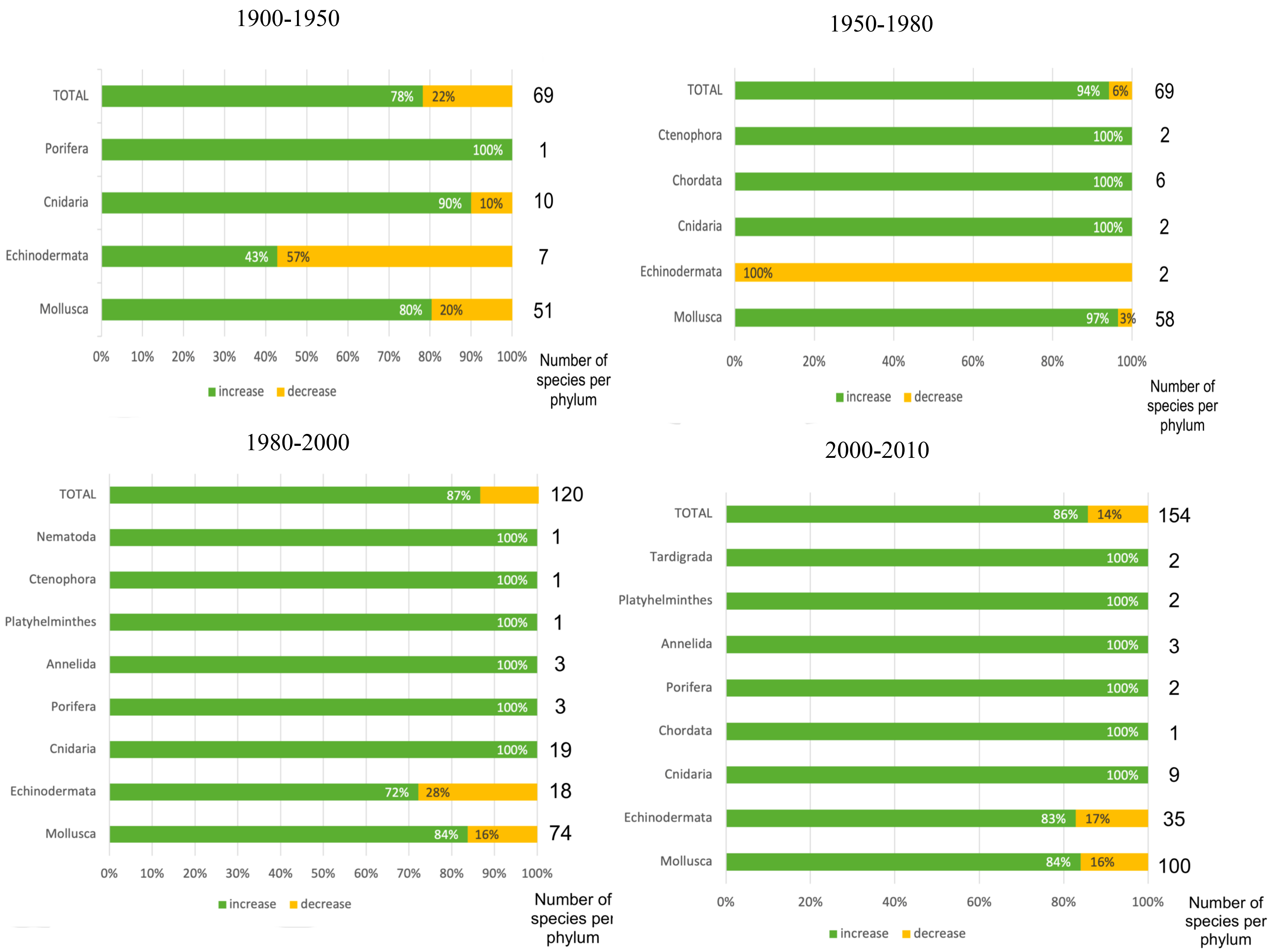


Figure 9: Direction of change of observation density of invertebrates over time per phylum from a given period compared to before 1900 in the Barents Sea.

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 *Ophiocten 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).

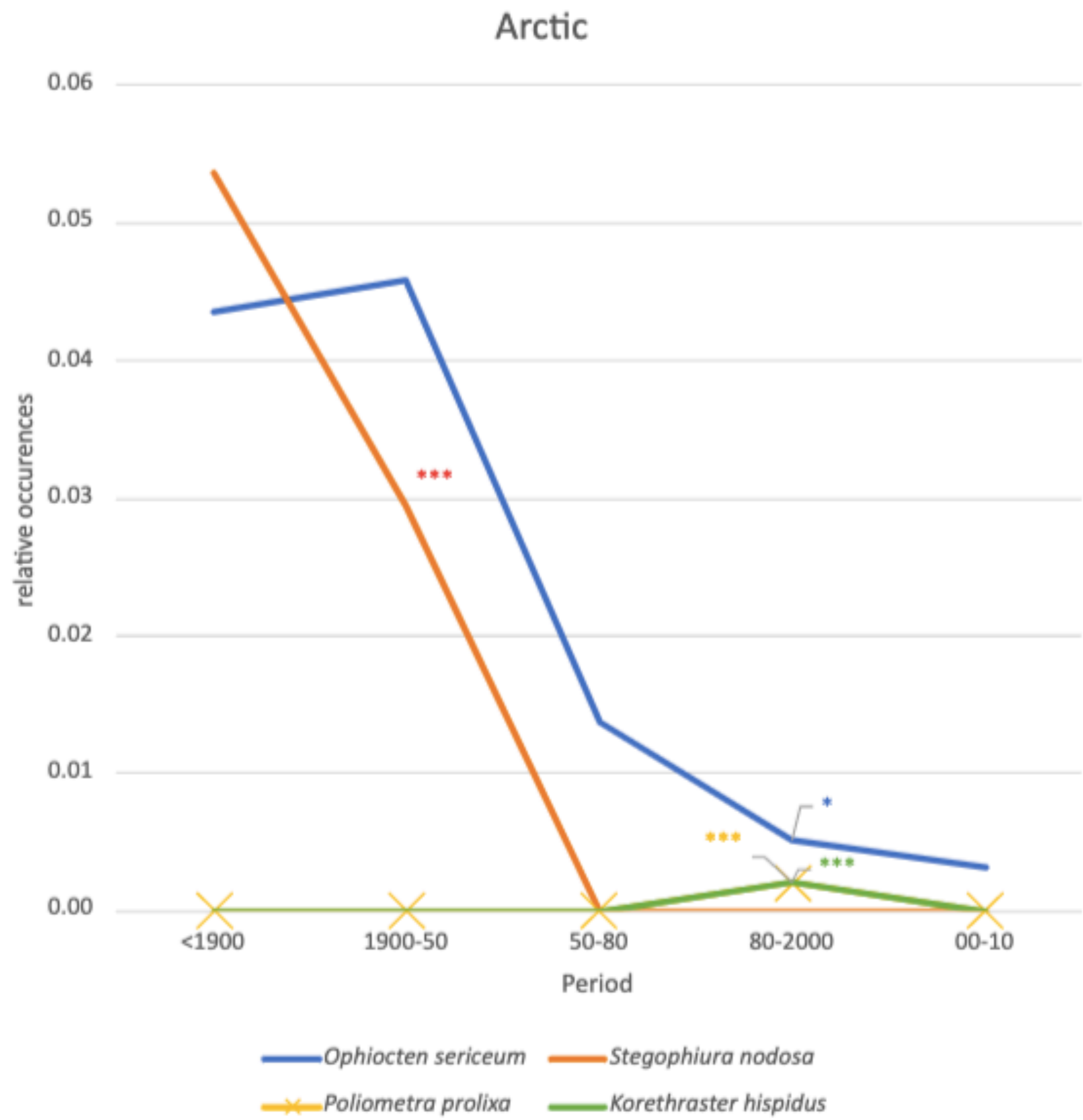


Figure 10*:* Number of corrected observations (i.e. offset applied) of four Arctic echinoderm species from before 1900 to 2010 in the Barents Sea. Y-axis: relative occurrence, X-axis: time periods. *Ophiocten sericeum:* "*" p<0.05, decreasing of the observation in 1980-2000; *Stegophiura nodosa*: "***" 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.

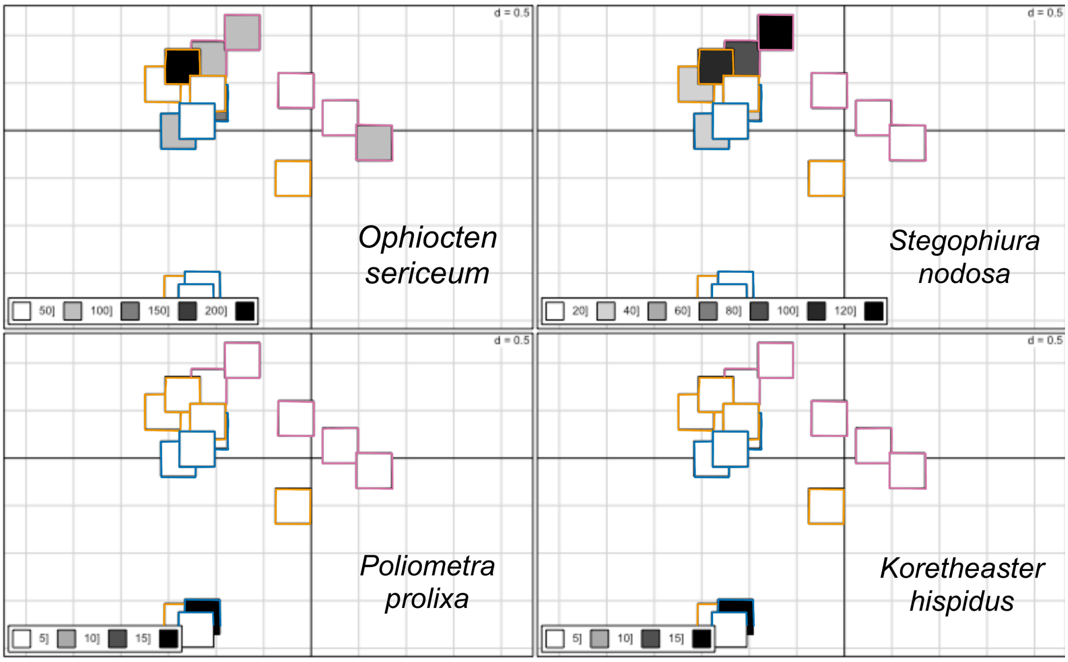


Figure 11: Zone · period specific abundances of four Arctic species, from the CA in Figure 6a. Colour of each box corresponds to the time per zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Amount of occurrence is given by the grey shading, with different scales for each 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).

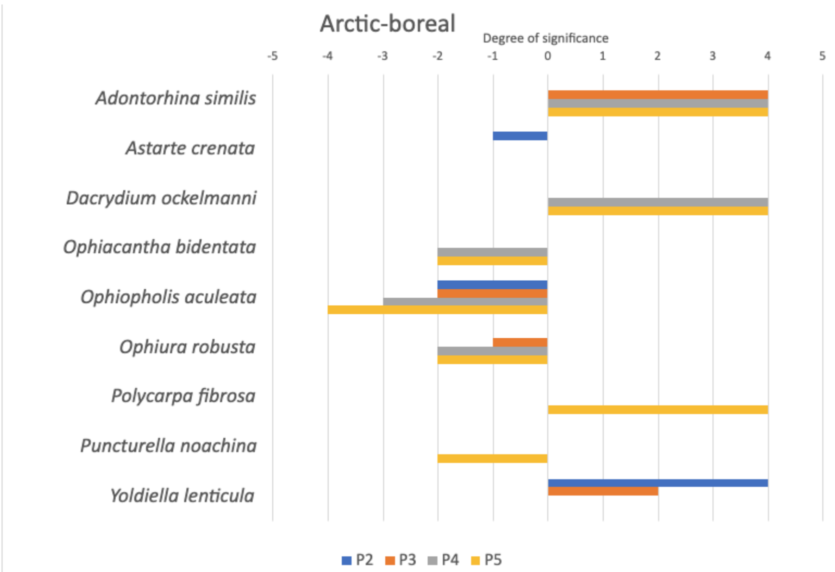


Figure 12: Degree of significance relating to the changes in number of corrected (i.e. offset applied to log-linear models) observations of Arctic-boreal species relative to before 1900 (P1, reference to P2 and hence not shown) to 2010 in the Barents Sea. Below 0: decrease of observation density, above 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.

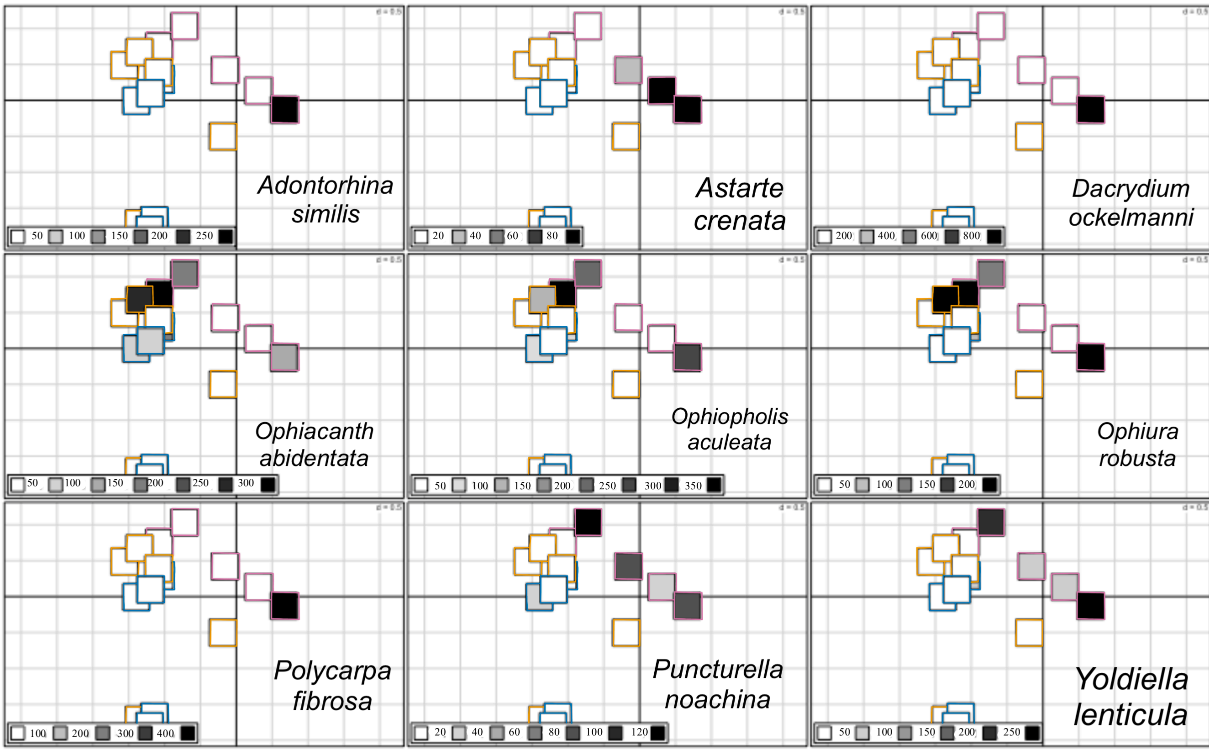


Figure 13: Correspondence analysis showing occurrence records of nine Arctic-boreal species over time. The colour of each box corresponds to the time frame by zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Gray shades show the bins of offset-corrected occurrence records. 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).

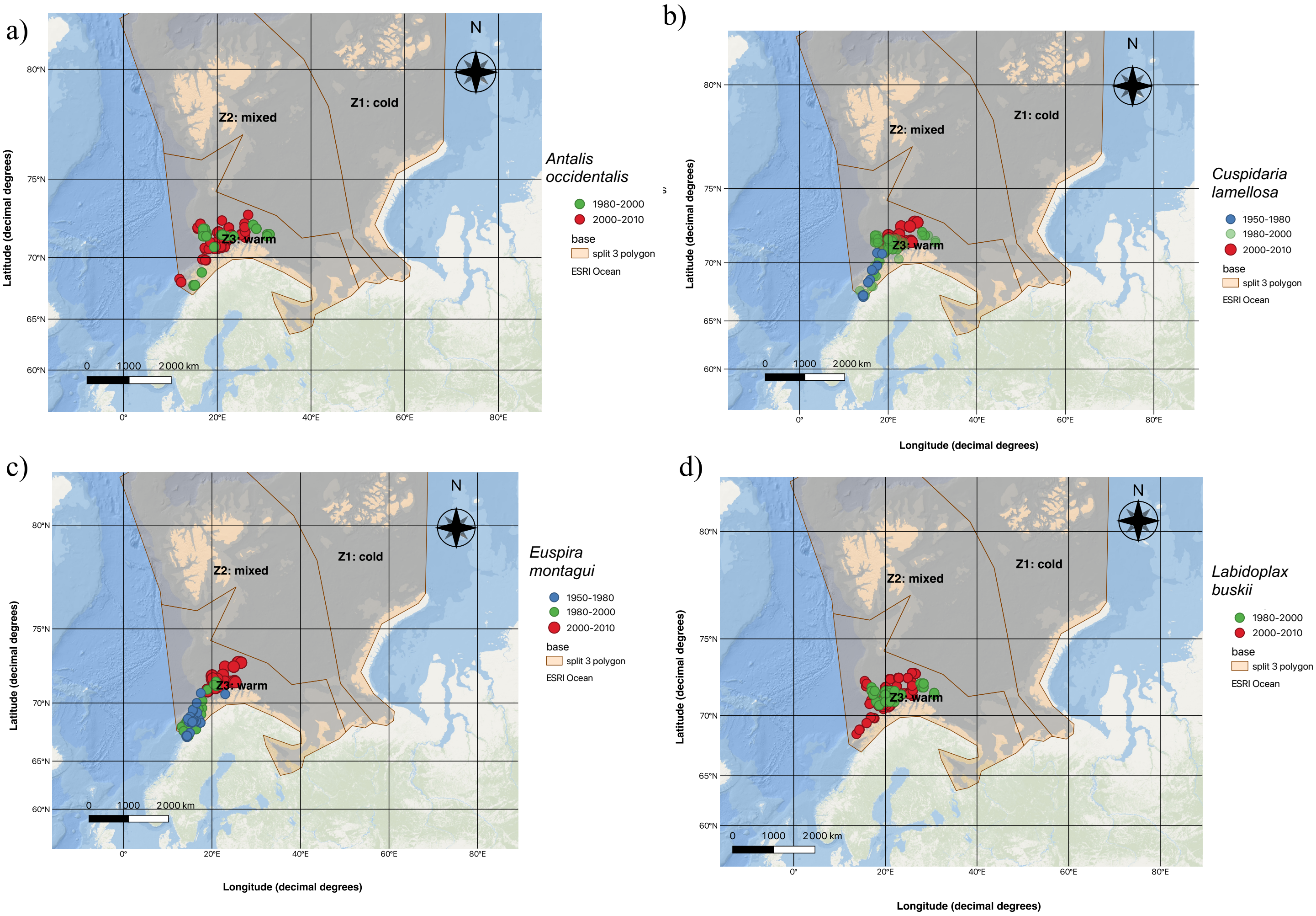


Figure 14: Map of the distribution of Arctic species in the Barents Sea a) *Antalis occidentalis*, b) *Cuspidaria lamellosa*, c) *Euspira montagui*, d) *Labidoplax buskii*. Blue dot: 1950-1980, green: 1980-2000, red: 2000-2010. Orange polygons represent the study zone and the three zones.

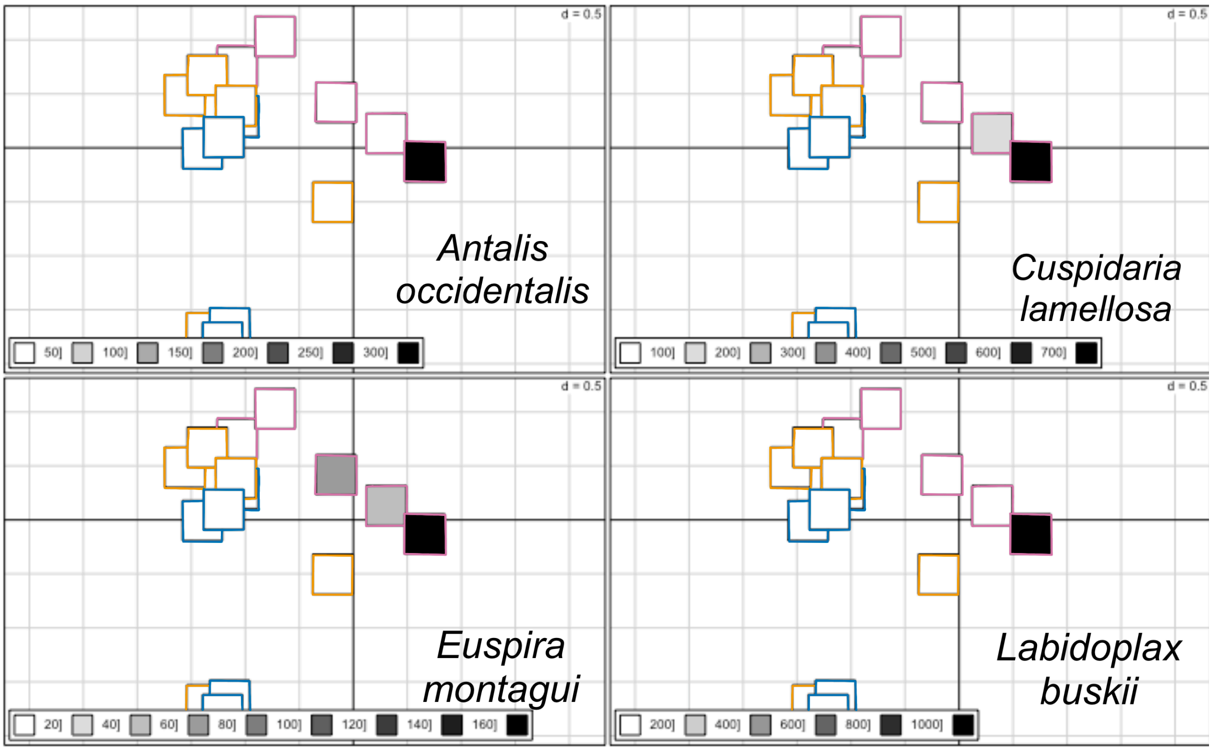


Figure 1511: Correspondance analysis of invertebrates in zone · periods in the Barents Sea with occurrence record density of four boreal species shown, colour of each box corresponds to the time per zone shown in Fig. 6a. Pink is Z3 warm, blue is Z2 mixed and yellow is Z1 cold. Occurrence densities increased 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 14th century (Roberts, 2002) although in the 19th 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 theses 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, ispotnature.org or 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^{th} 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. Coincidently, 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). Theses warmings in questions could have led the succinct shift in invertebrates observed and described after 1980 as well.

<u>1980-2000:</u>
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., *Ophiocten 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 60º 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 actiniarians 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.

<u>2000-2010:</u>
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 *Ophiocten 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 were 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 commons 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 American and the Norwegian coast. Using the GBIF occurrence map, 0 observation 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 observation 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 amphipods 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 1 300km (Węsławski 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.

Works cited

Allmon, W. D., & Hendricks, J. R. (2021). Gastropoda (Revised). In *The Digital Encyclopedia of Ancient Life*. https://www.digitalatlasofancientlife.org/learn/mollusca/gastropoda/](https://www.digitalatlasofancientlife.org/learn/mollusca/gastropoda/).

Altenburger, A., & Bergersen, R. (2023). *Gastropoda collection (TSZG)* Version 1.72) [occurence]. https://doi.org/https://doi.org/10.15468/8w7har

Arias-Ortiz, A., Serrano, O., Masqué, P., Lavery, P. S., Mueller, U., Kendrick, G. A., Rozaimi, M., Esteban, A., Fourqurean, J. W., Marbà, N., Mateo, M. A., Murray, K., Rule, M. J., & Duarte, C. M. (2018). A marine heatwave drives massive losses from the world's largest seagrass carbon stocks. *Nature Climate Change*, *8*, 338-344. https://doi.org/10.1038/s41558-018-0096-y

Årthun, M., Onarheim, I. H., Dörr, J., & Eldevik, T. (2021). The Seasonal and Regional Transition to an Ice-Free Arctic. *Geophysical Research Letters*, *48*. https://doi.org/10.1029/2020gl090825

Aschan, M., & Ingvaldsen, R. (2009). Recruitment of shrimp (*Pandalus borealis*) in the Barents Sea related to spawning stock and environment. *Deep Sea Research Part II: Topical Studies in Oceanography*, *56*, 2012-2022.

Asplin, L., Ingvaldsen, R., Loeng, H., & Sætre, R. (2001). Transport of Atlantic Water in the western Barents Sea. Journal

Beck, J., Ballesteros-Mejia, L., Buchmann, C. M., Dengler, J., Fritz, S. A., Gruber, B., Hof, C., Jansen, F., Knapp, S., Kreft, H., Schneider, A.-K., Winter, M., & Dormann, C. F. (2012). What's on the horizon for macroecology? *Ecography*, *35*, 673-683. https://doi.org/10.1111/j.1600-0587.2012.07364.x

Beck, J., Böller, M., Erhardt, A., & Schwanghart, W. (2014). Spatial bias in the GBIF database and its effect on modeling species' geographic distributions. *Ecological Informatics*, *19*, 10-15. https://doi.org/https://doi.org/10.1016/j.ecoinf.2013.11.002

Berge, J., Heggland, K., Lønne, O. J., Cottier, F., Hop, H., Gabrielsen, G. W., Nøttestad, L., & Misund, O. A. (2015). First records of Atlantic mackerel (*Scomber scombrus*) from the Svalbard archipelago, Norway, with possible explanations for the extensions of its distribution. *Arctic*, 54-61.

Berge, J., Johnsen, G., Nilsen, F., Gulliksen, B., & Slagstad, D. (2005). Ocean temperature oscillations enable reappearance of blue mussels *Mytilus edulis* in Svalbard after a 1000 year absence. *Marine Ecology Progress Series*, *303*, 167-175.

Beuchel, F., Gulliksen, B., & Carroll, M. L. (2006). Long-term patterns of rocky bottom macrobenthic community structure in an Arctic fjord (Kongsfjorden, Svalbard) in relation to climate variability (1980–2003). *Journal of Marine Systems*, *63*, 35-48.

Bluhm, B. A., Piepenburg, D., & Von Juterzenka, K. (1998). Distribution, standing stock, growth, mortality and production of *Strongylocentrotus pallidus* (Echinodermata: Echinoidea) in the northern Barents Sea. *Polar Biology*, *20*, 325-334. https://doi.org/10.1007/s003000050310

Boitsov, V. D., Karsakov, A. L., & Trofimov, A. G. (2012). Atlantic water temperature and climate in the Barents Sea, 2000–2009. *ICES Journal of Marine Science*, *69*, 833-840. https://doi.org/10.1093/icesjms/fss075

Bond, N. A., Cronin, M. F., Freeland, H., & Mantua, N. (2015). Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters*, *42*, 3414-3420.

Boshuizen, H. C., & Feskens, E. J. (2010). Fitting additive Poisson models. *Epidemiologic Perspectives & Innovations*, *7*, 1-4.

Braun, K., Leubner, F., & Stach, T. (2020). Phylogenetic analysis of phenotypic characters of Tunicata supports basal Appendicularia and monophyletic Ascidiacea. *Cladistics*, *36*, 259-300. https://doi.org/10.1111/cla.12405
Brotskaya, V., & Zenkevitch, L. (1939). Quantitative accounting of Barents Sea's benthic fauna. *Proceedings of VNIRO*, *4*, 1-150.
Cam, E., Nichols, J. D., Sauer, J. R., & Hines, J. E. (2002). On the Estimation of species richness based on the accumulation of previously unrecorded species. *Ecography*, *25*, 102-108. http://www.jstor.org/stable/3683635
Cautain, I. J., Last, K. S., McKee, D., Bluhm, B. A., Renaud, P. E., Ziegler, A. F., & Narayanaswamy, B. E. (2022). Uptake of sympagic organic carbon by the Barents Sea benthos linked to sea ice seasonality. *Frontiers in Marine Science*, *9*.
Chamberlain, S. A., & Boettiger, C. (2017). *R Python, and Ruby clients for GBIF species occurrence data* (e3304v1). PeerJ. https://dx.doi.org/10.7287/peerj.preprints.3304v1
Cherbonnier, G. (1969). Echinodermes récoltés par la «Thalassa» au large des côtes ouest de Bretagne et du Golfe de Gascogne (3–12 août 1967). *Bulletin du Muséum d'histoire naturelle*, *2*, 343-361.
Cheung, W. W. L., Lam, V. W. Y., Sarmiento, J. L., Kearney, K., Watson, R., & Pauly, D. (2009). Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries*, *10*, 235-251. https://doi.org/10.1111/j.1467-2979.2008.00315.x
Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., Ballesteros, E., Bianchi, C. N., Corbera, J., & Dailianis, T. (2010). The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. *PLOS ONE*, *5*, e11842.
Colwell, R. K., & Coddington, J. A. (1994). Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *345*, 101-118. https://doi.org/10.1098/rstb.1994.0091
Colwell, R. K., Mao, C. X., & Chang, J. (2004). Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology*, *85*, 2717-2727. https://doi.org/https://doi.org/10.1890/03-0557
Comiso, J. C. (2002). A rapidly declining perennial sea ice cover in the Arctic. *Geophysical Research Letters*, *29*, 17-11-17-14. https://doi.org/https://doi.org/10.1029/2002GL015650
Comiso, J. C., Parkinson, C. L., Gersten, R., & Stock, L. (2008). Accelerated decline in the Arctic sea ice cover. *Geophysical research letters*, *35, pages*.
Csapó, H. K., Grabowski, M., & Węsławski, J. M. (2021). Coming home-Boreal ecosystem claims Atlantic sector of the Arctic. *Science of the Total Environment*, *771*, 144817.
Dalpadado, P., Arrigo, K. R., van Dijken, G. L., Skjoldal, H. R., Bagøien, E., Dolgov, A. V., Prokopchuk, I. P., & Sperfeld, E. (2020). Climate effects on temporal and spatial dynamics of phytoplankton and zooplankton in the Barents Sea. *Progress in Oceanography*, *185*, 102320.
Degen, R., Jørgensen, L., Ljubin, P., Ellingsen, I., Pehlke, H., & Brey, T. (2016). Patterns and drivers of megabenthic secondary production on the Barents Sea shelf. *Marine Ecology Progress Series*, *546*, 1-16. https://doi.org/10.3354/meps11662
Drinkwater, K. (2009). Comparison of the response of Atlantic cod (*Gadus morhua*) in the high-latitude regions of the North Atlantic during the warm periods of the 1920s–1960s and the 1990s–2000s. *Deep Sea Research Part II: Topical Studies in Oceanography*, *56*, 2087-2096.
Drinkwater, K. F. (2006). The regime shift of the 1920s and 1930s in the North Atlantic. *Progress in Oceanography*, *68*, 134-151.
Dunn, S. (2021). *British Naval Trawlers and Drifters in Two World Wars: From the John Lambert Collection*. Seaforth Publishing.

Durieux, E. D., Morin, J., Alizier, S., Dauvin, J.-C., & Brind'Amour, A. (2010). Temporal changes in the spatial coupling between bentho-demersal fishes and their macrobenthic preys in the Seine estuary. *ICES*. incomplete

Edgecombe, G. D., Giribet, G., Dunn, C. W., Hejnol, A., Kristensen, R. M., Neves, R. C., Rouse, G. W., Worsaae, K., & Sørensen, M. V. (2011). Higher-level metazoan relationships: recent progress and remaining questions. *Organisms Diversity & Evolution*, *11*, 151-172. https://doi.org/10.1007/s13127-011-0044-4

Eernisse, D. J., Albert, J. S., & Anderson, F. E. (1992). Annelida and Arthropoda are Not Sister Taxa: A Phylogenetic Analysis of Spiralian Metazoan Morphology. *Systematic Biology*, *41*, 305-330. https://doi.org/10.1093/sysbio/41.3.305

Ekman, S. (1953). *Zoogeography of the Sea.* (2009/05/01 ed., Vol. 90). Cambridge University Press. https://doi.org/10.1017/S0016756800065663

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., & Taylor, K. E. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geoscientific Model Development*, *9*, 1937-1958. https://doi.org/10.5194/gmd-9-1937-2016

Fisher, R. A., Corbet, A. S., & Williams, C. B. (1943). The Relation Between the Number of Species and the Number of Individuals in a Random Sample of an Animal Population. *Journal of Animal Ecology*, *12*, 42-58. https://doi.org/10.2307/1411

Fortunato, S. A. V., Adamski, M., Ramos, O. M., Leininger, S., Liu, J., Ferrier, D. E. K., & Adamska, M. (2014). Calcisponges have a ParaHox gene and dynamic expression of dispersed NK homeobox genes. *Nature 514*, 620-623. https://doi.org/10.1038/nature13881

Fossheim, M., Primicerio, R., Johannesen, E., Ingvaldsen, R. B., Aschan, M. M., & Dolgov, A. V. (2015). Recent warming leads to a rapid borealization of fish communities in the Arctic. *Nature Climate Change*, *5*, 673-677.

Frainer, A., Primicerio, R., Kortsch, S., Aune, M., Dolgov, A. V., Fossheim, M., & Aschan, M. M. (2017). Climate-driven changes in functional biogeography of Arctic marine fish communities. *Proceedings of The National Academy of Sciences 114*, 12202-12207. https://doi.org/doi:10.1073/pnas.1706080114

Franchi, N., & Ballarin, L. (2017). Immunity in Protochordates: The Tunicate Perspective. *Frontiers in Immunology*, *8*. https://doi.org/10.3389/fimmu.2017.00674

Gage, J. (1991). Skeletal growth zones as age-markers in the sea urchin *Psammechinus miliaris*. *Marine Biology*, *110*, 217-228.

Garrabou, J., Coma, R., Bensoussan, N., Bally, M., Chevaldonné, P., Cigliano, M., Diaz, D., Harmelin, J. G., Gambi, M. C., Kersting, D. K., Ledoux, J. B., Lejeusne, C., Linares, C., Marschal, C., Pérez, T., Ribes, M., Romano, J. C., Serrano, E., Teixido, N., . . . Cerrano, C. (2009). Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave. *Global Change Biology*, *15*, 1090-1103. https://doi.org/10.1111/j.1365-2486.2008.01823.x

GBIF.org. (2023a). *Occurrence Download 1900-1950* The Global Biodiversity Information Facility. https://doi.org/10.15468/DL.YQ35UU

GBIF.org. (2023b). *Occurrence Download 1950-1980* The Global Biodiversity Information Facility. https://doi.org/10.15468/DL.H2EH33

GBIF.org. (2023c). *Occurrence Download 1980-2000* The Global Biodiversity Information Facility. https://doi.org/10.15468/DL.5RPZTM

GBIF.Org. (2023d). *Occurrence Download 2000-2010* The Global Biodiversity Information Facility. https://doi.org/10.15468/dl.awwr7m

GBIF.org. (2023e). *Occurrence Download before 1900* The Global Biodiversity Information Facility. https://doi.org/10.15468/DL.752R47

Gidden, M. J., Riahi, K., Smith, S. J., Fujimori, S., Luderer, G., Kriegler, E., Van Vuuren, D. P., Van Den Berg, M., Feng, L., Klein, D., Calvin, K., Doelman, J. C., Frank, S., Fricko, O., Harmsen, M., Hasegawa, T., Havlik, P., Hilaire, J., Hoesly, R., . . . Takahashi, K. (2019). Global emissions pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century. *Geoscientific Model Development*, *12*, 1443-1475. https://doi.org/10.5194/gmd-12-1443-2019

Giribet, G., & Edgecombe, G. D. (2020a). Before animals. In *The Invertebrate Tree of Life* (pp. 1-14). Princeton University Press. https://doi.org/10.2307/j.ctvscxrhm.5

Giribet, G., & Edgecombe, G. D. (2020b). Phylogenetics and the base of the animal tree of life. In *The Invertebrate Tree of Life* (pp. 15-22). Princeton University Press. https://doi.org/10.2307/j.ctvscxrhm.6

Giribet, G., Edgecombe, G. D., & Wheeler, W. C. (2001). Arthropod phylogeny based on eight molecular loci and morphology. *Nature*, *413*, 157-161. https://doi.org/10.1038/35093097

Graham, C. H., Elith, J., Hijmans, R. J., Guisan, A., Townsend Peterson, A., Loiselle, B. A., & Group, N. P. S. D. W. (2008). The influence of spatial errors in species occurrence data used in distribution models. *Journal of Applied Ecology*, *45*, 239-247.

Grebmeier, J. M., Frey, K. E., Cooper, L. W., & Kędra, M. (2018). Trends in benthic macrofaunal populations, seasonal sea ice persistence, and bottom water temperatures in the Bering Strait region. *Oceanography*, *31*, 136-151.

Greenacre, M., & Primicerio, R. (2014). *Multivariate analysis of ecological data*. Fundacion BBVA.

Guillou, M., & Michel, C. (1993). Reproduction and growth of *Sphaerechinus granularis* (Echinodermata: Echinoidea) in southern Brittany. *Journal of the Marine Biological Association of the United Kingdom*, *73*, 179-192.

Hastings, R. A., Rutterford, L. A., Freer, J. J., Collins, R. A., Simpson, S. D., & Genner, M. J. (2020). Climate change drives poleward increases and equatorward declines in marine species. *Current Biology*, *30*, 1572-1577. e1572.

Høisæter, T. (2009). Distribution of marine, benthic, shell bearing gastropods along the Norwegian coast. *Fauna Norvegica*, *28*. https://doi.org/10.5324/fn.v28i0.563 (Fauna Norvegica)

Jacques, G., Razouls, C., & Thiriot, A. (1969). Données météorologiques et hydrologiques de la région de banyuls-sur-mer année 1967-1968. *Vie et Milieu*, 63-74. https://hal.sorbonne-universite.fr/hal-02957867

Jetz, W., McPherson, J. M., & Guralnick, R. P. (2012). Integrating biodiversity distribution knowledge: toward a global map of life. *Trends in Ecology & Evolution*, *27*, 151-159. https://doi.org/10.1016/j.tree.2011.09.007

Johannesen, E., Jørgensen, L. L., Fossheim, M., Primicerio, R., Greenacre, M., Ljubin, P. A., Dolgov, A. V., Ingvaldsen, R. B., Anisimova, N. A., & Manushin, I. E. (2017). Large-scale patterns in community structure of benthos and fish in the Barents Sea. *Polar Biology*, *40*, 237-246. https://doi.org/10.1007/s00300-016-1946-6

Jørgensen, L. L., Ljubin, P., Skjoldal, H. R., Ingvaldsen, R. B., Anisimova, N., & Manushin, I. (2014). Distribution of benthic megafauna in the Barents Sea: baseline for an ecosystem approach to management. *ICES Journal of Marine Science*, *72*, 595-613. https://doi.org/10.1093/icesjms/fsu106

Kantor, Y. I., Rusyaev, S. M., & Antokhina, T. I. (2008). Going eastward—climate changes evident from gastropod distribution in the Barents Sea. *Ruthenica*, *18*, 51-54.

Kim, K. C. (1993). Biodiversity, conservation and inventory: why insects matter. *Biodiversity & Conservation*, *2*, 191-214.

Kortsch, S., Primicerio, R., Beuchel, F., Renaud, P. E., Rodrigues, J., Lønne, O. J., & Gulliksen, B. (2012). Climate-driven regime shifts in Arctic marine benthos. *Proceedings of the National Academy of Sciences*, *109*, 14052-14057.
Kortsch, S., Primicerio, R., Fossheim, M., Dolgov, A. V., & Aschan, M. (2015). Climate change alters the structure of arctic marine food webs due to poleward shifts of boreal generalists. *Proceedings of the Royal Society B: Biological Sciences*, *282*, 20151546. https://doi.org/10.1098/rspb.2015.1546
Landy, J. C., Dawson, G. J., Tsamados, M., Bushuk, M., Stroeve, J. C., Howell, S. E. L., Krumpen, T., Babb, D. G., Komarov, A. S., Heorton, H. D. B. S., Belter, H. J., & Aksenov, Y. (2022). A year-round satellite sea-ice thickness record from CryoSat-2. *Nature*, *609*, 517-522. https://doi.org/10.1038/s41586-022-05058-5
Leather, S. R. (2013). Institutional vertebratism hampers insect conservation generally; not just saproxylic beetle conservation. *Animal Conservation*, *16*, 379-380.
Lenoir, J., Bertrand, R., Comte, L., Bourgeaud, L., Hattab, T., Murienne, J., & Grenouillet, G. (2020). Species better track climate warming in the oceans than on land. *Nature Ecology & Evolution*, *4*, 1044-1059. https://doi.org/10.1038/s41559-020-1198-2
Levitus, S., Matishov, G., Seidov, D., & Smolyar, I. (2009). Barents Sea multidecadal variability. *Geophysical Research Letters*, *36*.
Lind, S., Ingvaldsen, R. B., & Furevik, T. (2018). Arctic warming hotspot in the northern Barents Sea linked to declining sea-ice import. *Nature Climate Change*, *8*, 634-639. https://doi.org/10.1038/s41558-018-0205-y
Loeng, H. (1991). Features of the physical oceanographic conditions of the Barents Sea. *Polar Research*, *10*, 5-18. https://doi.org/10.3402/polar.v10i1.6723
Loeng, H. (1997). Water fluxes through the Barents Sea. *ICES Journal of Marine Science*, *54*, 310-317. https://doi.org/10.1006/jmsc.1996.0165
Maldonado, C., Molina, C. I., Zizka, A., Persson, C., Taylor, C. M., Albán, J., Chilquillo, E., Rønsted, N., & Antonelli, A. (2015). Estimating species diversity and distribution in the era of Big Data: to what extent can we trust public databases? *Global Ecology and Biogeography*, *24*, 973-984. https://doi.org/https://doi.org/10.1111/geb.12326
Massin, C., Robar-Matheson, A., Hamel, J.-F., & Mercier, A. (2014). First records of *Thyone inermis* and *Labidoplax buskii* (Echinodermata: Holothuroidea) in Canadian waters. *Marine Biodiversity Records*, *7*. https://doi.org/10.1017/s1755267214001249
Meglitsch, P. A., & Schram, F. R. (1991). *Invertebrate Zoology*. Oxford University Press. https://books.google.no/books?id=yp3wAAAAMAAJ
Mohamed, B., Nilsen, F., & Skogseth, R. (2022). Marine Heatwaves Characteristics in the Barents Sea Based on High Resolution Satellite Data (1982–2020). *Frontiers in Marine Science*, *13*, 4436.
Monitoring (Really?), A. (2018). AMAP Assessment 2018: Arctic Ocean Acidification.
Mueter, F. J., & Litzow, M. A. (2008). Sea ice retreat alters the biogeography of the Bering Sea continental shelf. *Ecological Applications*, *18*, 309-320.
Nascimento, M. C., Husson, B., Guillet, L., & Pedersen, T. (2023). Modelling the spatial shifts of functional groups in the Barents Sea using a climate-driven spatial food web model. *Ecological Modelling*, *481*, 110358.
Nekhaev, I. (2014). Marine shell-bearing Gastropoda of Murman (Barents Sea): an annotated check-list. *Ruthenica*, *24*, 75-121.
Nekhaev, I. O. (2016). Newly arrived or previously overlooked: is there evidence for climate-driven changes in the distribution of molluscs in the Barents Sea? *Biodiversity and Conservation*, *25*, 807-825. https://doi.org/10.1007/s10531-016-1104-z (Biodiversity and Conservation)

Nekhaev, I. O., & Krol, E. N. (2017). Diversity of shell-bearing gastropods along the western coast of the Arctic archipelago Novaya Zemlya: an evaluation of modern and historical data. *Polar Biology*, *40*, 2279-2289. https://doi.org/10.1007/s00300-017-2140-1 (Polar Biology)
Nekhaev, I. O., & Merkuliev, A. V. (2021). Missing and misidentified museum specimens hinder long-term monitoring: a case study of shell-bearing gastropods from the Kola Meridian transect, Barents Sea. *Polar Research*, *40*. https://doi.org/10.33265/polar.v40.4999
Pearson, T. H., Mannvik, H.-P., Evans, R., & Falk-Petersen, S. (1996). The benthic communities of the Snorre field in the Northern North Sea (61 30′ N 2 10′ E): 1. The distribution and structure of communities in undisturbed sediments. *Journal of Sea Research*, *35*, 301-314.
Peterson, K. J., & Eernisse, D. J. (2001). Animal phylogeny and the ancestry of bilaterians: inferences from morphology and 18S rDNA gene sequences. *Evolution and Development*, *3*, 170-205. https://doi.org/10.1046/j.1525-142x.2001.003003170.x
Peura, J. F., Lovvorn, J. R., North, C. A., & Kolts, J. M. (2013). Hermit crab population structure and association with gastropod shells in the northern Bering Sea. *Journal of Experimental Marine Biology and Ecology*, *449*, 10-16. https://doi.org/https://doi.org/10.1016/j.jembe.2013.08.009
Polyakov, I. V., Alkire, M. B., Bluhm, B. A., Brown, K. A., Carmack, E. C., Chierici, M., Danielson, S. L., Ellingsen, I., Ershova, E. A., Gårdfeldt, K., Ingvaldsen, R. B., Pnyushkov, A. V., Slagstad, D., & Wassmann, P. (2020). Borealization of the Arctic Ocean in Response to Anomalous Advection From Sub-Arctic Seas. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/fmars.2020.00491
R Development Core Team. (2010). *R: A Language and Environment for Statistical Computing*. In https://www.R-project.org/
Rantanen, M., Karpechko, A. Y., Lipponen, A., Nordling, K., Hyvärinen, O., Ruosteenoja, K., Vihma, T., & Laaksonen, A. (2022). The Arctic has warmed nearly four times faster than the globe since 1979. *Communications Earth & Environment*, *3*, 168. https://doi.org/10.1038/s43247-022-00498-3
Regier, J. C., Shultz, J. W., Zwick, A., Hussey, A., Ball, B., Wetzer, R., Martin, J. W., & Cunningham, C. W. (2010). Arthropod relationships revealed by phylogenomic analysis of nuclear protein-coding sequences. *Nature*, *463*, 1079-1083. https://doi.org/10.1038/nature08742
Roberts, C. M. (2002). Deep impact: the rising toll of fishing in the deep sea. *Trends in Ecology & Evolution*, *17*, 242-245.
Rocha-Ortega, M., Rodriguez, P., & Córdoba-Aguilar, A. (2021). Geographical, temporal and taxonomic biases in insect GBIF data on biodiversity and extinction. *Ecological Entomology*, *46*, 718-728. https://doi.org/10.1111/een.13027
Salvigsen, O. (2002). Radiocarbon-dated *Mytilus edulis* and *Modiolus modiolus* from northern Svalbard: Climatic implications. *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography*, *56*, 56-61. https://doi.org/10.1080/002919502760056350
Scheibling, R., Feehan, C., & Lauzon-Guay, J.-S. (2013). Climate change, disease and the dynamics of a kelp-bed ecosystem in Nova Scotia. In (Vol. 361-387) incomplete.
Schmidt-Rhaesa, A., Harzsch, S., & Purschke, G. (2015). *Structure and evolution of invertebrate nervous systems*. Oxford University Press.
Sejr, M., Sand, M., Jensen, K., Petersen, J., Christensen, P., & Rysgaard, S. (2002). Growth and production of *Hiatella arctica* (Bivalvia) in a high-Arctic fjord (Young Sound, Northeast Greenland). *Marine Ecology Progress Series*, *244*, 163-169. https://doi.org/10.3354/meps244163

Simkanin, C., Power, A. M., Myers, A., McGrath, D., Southward, A., Mieszkowska, N., Leaper, R., & O'Riordan, R. (2005). Using historical data to detect temporal changes in the abundances of intertidal species on Irish shores. *Journal of the Marine Biological Association of the United Kingdom*, *85*, 1329-1340.

Skagseth, Ø., Eldevik, T., Årthun, M., Asbjørnsen, H., Lien, V. S., & Smedsrud, L. H. (2020). Reduced efficiency of the Barents Sea cooling machine. *Nature Climate Change*, *10*, 661-666. https://doi.org/10.1038/s41558-020-0772-6

Smedsrud, L. H., Muilwijk, M., Brakstad, A., Madonna, E., Lauvset, S. K., Spensberger, C., Born, A., Eldevik, T., Drange, H., & Jeansson, E. (2022). Nordic Seas heat loss, Atlantic inflow, and Arctic sea ice cover over the last century. *Reviews of Geophysics*, *60*, e2020RG000725.

Smith, G. E. (1911). Vorlesungen über vergleichende Anatomie. *Nature*, *87*, 104-105. https://doi.org/10.1038/087104a0

Snigirov, S., Sizo, R., & Sylantyev, S. (2013). Lodgers or tramps? *Aporrhais pespelecani* and *Turritella communis* on the north-western Black Sea shelf. *Marine Biodiversity Records*, *6*.

Soberón, J., Arriaga, L., & Lara, L. (2002). Issues of quality control in large, mixed-origin entomological databases. *Towards a global biological information infrastructure*, *70*, 15-22.

Steiner, G., & Kabat, A. R. (2004). *Catalog of species-group names of Recent and fossil Scaphopoda (Mollusca)*. Publications Scientifiques du Muséum national d'Histoire naturelle Paris.

Thioulouse, J., Dray, S., Dufour, A.-B., Siberchicot, A., Jombart, T., & Pavoine, S. (2018). Multivariate analysis of ecological data with ade4. *R package*.

Thomsen, E., & Vorren, T. O. (1986). Macrofaunal palaeoecology and stratigraphy in late quaternary shelf sediments off Northern Norway. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *56*, 103-150. https://doi.org/https://doi.org/10.1016/0031-0182(86)90110-0

Thomsen, M. S., Mondardini, L., Alestra, T., Gerrity, S., Tait, L., South, P. M., Lilley, S. A., & Schiel, D. R. (2019). Local extinction of bull kelp (*Durvillaea* spp.) due to a marine heatwave. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/fmars.2019.00084

Timmermans, M., Ladd, C., & Wood, K. (2015). Sea surface temperature, Arctic Report Card. In. NOAA technical report OAR ARC.

Trainer, V. L., Kudela, R. M., Hunter, M. V., Adams, N. G., & McCabe, R. M. (2020). Climate extreme seeds a new domoic acid hotspot on the US west coast. *Frontiers in Climate*, *2*, 571836.

Ursin, E. (1960). *A quantitative investigation of the echinoderm fauna of the central North Sea*. CA Reitzels.

Van Veen, J. (1936). Onderzoekingen in de Hoofden in verband met de gesteldheid der Nederlandsche kust. *PhD thesis-universiteit van Leiden*.

von Biela, V. R., Laske, S. M., Stanek, A. E., Brown, R. J., & Dunton, K. H. (2023). Borealization of nearshore fishes on an interior Arctic shelf over multiple decades. *Global Change Biology*, *29*, 1822-1838. https://doi.org/https://doi.org/10.1111/gcb.16576

Warton, D. I. (2022). *Eco-Stats: Data Analysis in Ecology: From t-tests to Multivariate Abundances*. Springer Nature.

Wassmann, P., Reigstad, M., Haug, T., Rudels, B., Carroll, M. L., Hop, H., Gabrielsen, G. W., Falk-Petersen, S., Denisenko, S. G., Arashkevich, E., Slagstad, D., & Pavlova, O. (2006). Food webs and carbon flux in the Barents Sea. *Progress in Oceanography*, *71*, 232-287. https://doi.org/https://doi.org/10.1016/j.pocean.2006.10.003

Węsławski, J. M., Dragańska-Deja, K., Legeżyńska, J., & Walczowski, W. (2018). Range extension of a boreal amphipod *Gammarus oceanicus* in the warming Arctic. *Ecology and Evolution*, *8*, 7624-7632.

Wessels, B., Finn, R. L., Linde, P., Mazzetti, P., Nativi, S., Riley, S., Smallwood, R., Taylor, M. J., Tsoukala, V., Wadhwa, K., & Wyatt, S. (2014). Issues in the development of open access to research data. *Prometheus*, *32*, 49-66. https://doi.org/10.1080/08109028.2014.956505

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., Da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., . . . Mons, B. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, *3*, 160018. https://doi.org/10.1038/sdata.2016.18

Yesson, C., Brewer, P. W., Sutton, T., Caithness, N., Pahwa, J. S., Burgess, M., Gray, W. A., White, R. J., Jones, A. C., Bisby, F. A., & Culham, A. (2007). How global is the Global Biodiversity Information Facility? *PLOS ONE*, *2*, e1124. https://doi.org/10.1371/journal.pone.0001124

Yu, H., Wang, T., Skidmore, A., Heurich, M., & Bässler, C. (2022). 50 Years of cumulative open-source data confirm stable and robust biodiversity distribution patterns for macrofungi. *Journal of Fungi*, *8*, 981. https://doi.org/10.3390/jof8090981

Zakharov, Anisimova, Manushin, Zimina, O., Jørgensen, L., Любин, П., Nosova, T., N.E, Z., Golikov, A., & Daria Yuryevna, B. (2018). *АТЛАС МЕГАБЕНТОСНЫХ ОРГАНИЗМОВ БАРЕНЦЕВА МОРЯ И СОПРЕДЕЛЬНЫХ АКВАТОРИЙ (Atlas of the megabenthic organisms of the Barents Sea and adjacent waters)*. publisher?

Zakharov, & Jørgensen. (2017). New species of the gastropods in the Barents Sea and adjacent waters. *Russian Journal of Biological Invasions*, *8*, 226-231. https://doi.org/10.1134/S2075111717030146

Zakharov, Jørgensen, Manushin, & Strelkova. (2020). Barents Sea megabenthos: Spatial and temporal distribution and production. *Marine Biological Journal*, *5*, 19-37. https://doi.org/10.21072/mbj.2020.05.2.03

Zrzavý, J., Mihulka, S., Kepka, P., Bezděk, A., & Tietz, D. (1998). Phylogeny of the metazoa based on morphological and 18S ribosomal DNA evidence. *Cladistics*, *14*, 249-285. https://doi.org/https://doi.org/10.1111/j.1096-0031.1998.tb00338.x

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
Abra longicallus	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Abra nitida	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Abra prismatica	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Acanthocardia echinata	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Acanthotrochus mirabilis	Echinodermata	Holothuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Aclis sarsi	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Admete viridula	Mollusca	Gastropoda	poisson	none					none				
Adontorhina similis	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Aeginopsis laurentii	Cnidaria	Hydrozoa	quasipoisson	none					none				
Aeolidia papillosa	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Aglantha digitale	Cnidaria	Hydrozoa	quasipoisson	none					none				
Akera bullata	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Allantactis parasitica	Cnidaria	Anthozoa	poisson	none					yes			0,05	
Alvania cimicoides	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Alvania punctura	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Alvania subsoluta	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Amauropsis islandica	Mollusca	Gastropoda	poisson	none					none				
Amphilepis norvegica	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Amphipholis squamata	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Amphiura borealis	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Amphiura filiformis	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Amphiura securigera	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001		yes			0,001	
Anatoma crispata	Mollusca	Gastropoda	quasipoisson	none					none				
Antalis agilis	Mollusca	Scaphopoda	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Antalis entalis	Mollusca	Scaphopoda	quasipoisson	none					none				
Antalis occidentalis	Mollusca	Scaphopoda	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Aplysilla sulfurea	Porifera	Demospongiae	quasipoisson	yes				0,001	yes				0,001
Aporrhais pespelecani	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Arctica islandica	Mollusca	Bivalvia	poisson	yes				0,01	yes	0,01		0,001	0,001
Ariadnaria borealis	Mollusca	Gastropoda	poisson	none					none				
Arianta arbustorum	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Arion fuscus	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
Ascidia obliqua	Chordata	Ascidiacea	quasipoisson	yes		0,001			yes		0,001		
Astarte crenata	Mollusca	Bivalvia	quasipoisson	yes	-0,1				yes			0,05	0,05
Astarte elliptica	Mollusca	Bivalvia	quasipoisson	yes	-0,05		-0,05	-0,01	none				
Astarte montagui	Mollusca	Bivalvia	quasipoisson	yes	-0,1		-0,1	-0,05	none				
Astarte sulcata	Mollusca	Bivalvia	poisson	none					none				
Asterias rubens	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes				0,001
Astyris rosacea	Mollusca	Gastropoda	poisson	none					none				
Aulactinia stella	Cnidaria	Anthozoa	quasipoisson	yes	0,001				yes	0,001			
Aurelia aurita	Cnidaria	Scyphozoa	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Axinopsida orbiculata	Mollusca	Bivalvia	poisson	yes	-0,01			-0,05	yes	-0,1			
Axinulus croulinensis	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Bathyarca frielei	Mollusca	Bivalvia	Quasipoisson	none					none				
Bathyarca pectunculoides	Mollusca	Bivalvia	poisson	none					none				
Bathycrinus carpenterii	Echinodermata	Crinoidea	quasipoisson	none					none				
Bathyomphalus contortus	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Bathypolypus arcticus	Mollusca	Cephalopoda	quasipoisson	yes			0,001		yes			0,001	
Beroe cucumis	Ctenophora	Nuda	poisson	none					none				
Bolinopsis infundibulum	Ctenophora	Tentaculata	quasipoisson	yes		0,001			yes		0,001		
Boltenia echinata	Chordata	Ascidiacea	quasipoisson	yes		0,001			yes		0,001		
Boreacola maltzani	Mollusca	Bivalvia	quasipoisson	yes			0,001		yes			0,001	
Boreochiton ruber	Mollusca	Polyplacophora	poisson	yes	0,001	0,05			yes	0,001	0,001		
Boreotrophon clathratus	Mollusca	Gastropoda	poisson	none					none				
Boreotrophon clavatus	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Boreotrophon truncatus	Mollusca	Gastropoda	quasipoisson	none					none				
Botrylloides aureus	Chordata	Ascidiacea	poisson	none					none				
Bougainvillia superciliaris	Cnidaria	Hydrozoa	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Brattegardia nanseni	Porifera	Calcarea	quasipoisson	yes	0,001				yes	0,001			
Brisaster fragilis	Echinodermata	Echinoidea	quasipoisson	yes				0,001	yes				0,001
Brissopsis lyrifera	Echinodermata	Echinoidea	quasipoisson	yes				0,001	yes				0,001
Buccinum cyaneum	Mollusca	Gastropoda	quasipoisson	none					none				
Buccinum finmarkianum	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Cactosoma abyssorum	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
Cadulus jeffreysi	Mollusca	Scaphopoda	quasipoisson	yes				0,001	yes				0,001
Cadulus propinquus	Mollusca	Scaphopoda	quasipoisson	yes				0,001	yes				0,001
Cadulus subfusiformis	Mollusca	Scaphopoda	quasipoisson	yes				0,001	yes				0,001
Calliostoma occidentale	Mollusca	Gastropoda	quasipoisson	yes	0,001			-0,001	yes	0,001			-0,001
Calycella syringa	Cnidaria	Hydrozoa	quasipoisson	yes	0,001				yes	0,001			
Campanularia volubilis	Cnidaria	Hydrozoa	poisson	none					none				
Capulus ungaricus	Mollusca	Gastropoda	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Cardiomya cadiziana	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Ceramaster granularis	Echinodermata	Asteroidea	quasipoisson	none					none				
Cerastoderma edule	Mollusca	Bivalvia	quasipoisson	yes	0,001	0,001			yes	0,001	0,001		
Cerithiella metula	Mollusca	Gastropoda	quasipoisson	none					none				
Chaetoderma nitidulum	Mollusca	Caudofoveata	quasipoisson	yes		0,001			yes		0,001		
Chamelea striatula	Mollusca	Bivalvia	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Cladorhiza gelida	Porifera	Demospongiae	quasipoisson	yes			0,001		yes			0,001	
Clausilia bidentata	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Clelandella miliaris	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Clione limacina	Mollusca	Gastropoda	poisson	none					none				
Colus gracilis	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Coryphella verrucosa	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Crenella decussata	Mollusca	Bivalvia	quasipoisson	none					none				
Crossaster papposus	Echinodermata	Asteroidea	quasipoisson	yes	-0,01			-0,001	yes				-0,05
Ctenodiscus crispatus	Echinodermata	Asteroidea	quasipoisson	none					none				
Curtitoma trevelliana	Mollusca	Gastropoda	quasipoisson	none					none				
Curtitoma violacea	Mollusca	Gastropoda	quasipoisson	none					none				
Cuspidaria lamellosa	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Cuspidaria obesa	Mollusca	Bivalvia	quasipoisson	none					none				
Cuspidaria subtorta	Mollusca	Bivalvia	quasipoisson	none					none				
Cyanea capillata	Cnidaria	Scyphozoa	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Cyclopecten hoskynsi	Mollusca	Bivalvia	quasipoisson	none					yes				0,10
Cylista splendens	Cnidaria	Anthozoa	quasipoisson	yes			0,001		yes			0,001	
Cyrillia aequalis	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Cyrillia linearis	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		

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

SPECIES	PYHLUM	CLASS	TEST	WITH OFFSET CHANGES?	P2	P3	P4	P5	WITHOUT OFFSET CHANGES ?	W/o P2	W/o P3	W/o P4	W/o P5
Euspira nitida	Mollusca	Gastropoda	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Flabellum macandrewi	Cnidaria	Anthozoa	quasipoisson	yes				0,001	yes				0,001
Frigidoalvania janmayeni	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Galba truncatula	Mollusca	Gastropoda	poisson	yes		-0,1			none				
Genaxinus eumyarius	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Glandulactis spetsbergensis	Cnidaria	Anthozoa	quasipoisson	yes			0,001		yes			0,001	
Golfingia margaritacea	Annelida		quasipoisson	none					none				
Golfingia vulgaris	Annelida		quasipoisson	none					none				
Gorgonocephalus arcticus	Echinodermata	Ophiuroidea	quasipoisson	yes	0,001				yes	0,001			
Gorgonocephalus eucnemis	Echinodermata	Ophiuroidea	quasipoisson	none					yes	0,05			
Gracilechinus acutus	Echinodermata	Echinoidea	quasipoisson	yes				0,001	yes				0,001
Grammaria abietina	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Gyrodactylus albolacustris	Platyhelminthes	Monogenea	quasipoisson	yes				0,001	yes				0,001
Gyrodactylus arcuatus	Platyhelminthes	Monogenea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Halcampa arctica	Cnidaria	Anthozoa	poisson	none					none				
Halecium beanii	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Halecium labrosum	Cnidaria	Hydrozoa	poisson	none					yes			0,05	
Haliella stenostoma	Mollusca	Gastropoda	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Halitholus yoldiaearcticae	Cnidaria	Hydrozoa	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Halocynthia pyriformis	Chordata	Ascidiacea	quasipoisson	none					none				
Hanleya hanleyi	Mollusca	Polyplacophora	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Henricia perforata	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes				0,001
Henricia sanguinolenta	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes				0,001
Hermania scabra	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Heteranomia squamula	Mollusca	Bivalvia	poisson	none					none				
Hiatella rugosa	Mollusca	Bivalvia	quasipoisson	none					none				
Hippasteria phrygiana	Echinodermata	Asteroidea	quasipoisson	none					none				
Hormathia digitata	Cnidaria	Anthozoa	quasipoisson	none					none				
Hormathia nodosa	Cnidaria	Anthozoa	poisson	none					none				
Hydractinia carica	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Hydrallmania falcata	Cnidaria	Hydrozoa	quasipoisson	yes	0,001				yes	0,001			
Iothia fulva	Mollusca	Gastropoda	quasipoisson	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
Isohypsibius prosostomus	Tardigrada	Eutardigrada	quasipoisson	yes				0,001	yes				0,001
Kadosactis rosea	Cnidaria	Anthozoa	quasipoisson	yes			0,001		yes			0,001	
Karnekampia sulcata	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Kellia suborbicularis	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Kelliella miliaris	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Kophobelemnon stelliferum	Cnidaria	Anthozoa	quasipoisson	yes				0,001	yes				0,001
Korethraster hispidus	Echinodermata	Asteroidea	quasipoisson	yes			0,001		yes			0,001	
Kurtiella bidentata	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Labidoplax buskii	Echinodermata	Holothuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Lacuna crassior	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Lacuna pallidula	Mollusca	Gastropoda	poisson	none					none				
Lacuna parva	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Lacuna vincta	Mollusca	Gastropoda	poisson	yes	0,100	0,001		-0,001	yes	0,001	0,001	0,001	0,10
Laeocochlis sinistrata	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Lafoea dumosa	Cnidaria	Hydrozoa	quasipoisson	none					none				
Laona quadrata	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Ledella messanensis	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Lepeta caeca	Mollusca	Gastropoda	quasipoisson	none					none				
Lepidochitona cinerea	Mollusca	Polyplacophora	quasipoisson	yes	0,001				yes	0,001			
Leptaxinus minutus	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Leptochiton alveolus	Mollusca	Polyplacophora	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Leptochiton arcticus	Mollusca	Polyplacophora	poisson	yes	0,05	0,01		-0,001	yes	0,001	0,001		
Leptochiton asellus	Mollusca	Polyplacophora	quasipoisson	none					none				
Leptychaster arcticus	Echinodermata	Asteroidea	quasipoisson	none					none				
Limacina helicina	Mollusca	Gastropoda	quasipoisson	none					none				
Limacina retroversa	Mollusca	Gastropoda	quasipoisson	none					none				
Limatula gwyni	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Limatula subauriculata	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Limea crassa	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Limopsis aurita	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Limopsis cristata	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Limopsis minuta	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
Liocyma fluctuosa	Mollusca	Bivalvia	poisson	yes	-0,001		-0,001		yes	-0,001			
Littorina littorea	Mollusca	Gastropoda	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Littorina saxatilis	Mollusca	Gastropoda	quasipoisson	yes			-0,1	-0,05	yes	0,001			
Lophaster furcifer	Echinodermata	Asteroidea	poisson	none					yes	0,05			
Lucinoma borealis	Mollusca	Bivalvia	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Luidia sarsii	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes				0,001
Lyonsia arenosa	Mollusca	Bivalvia	poisson	yes					yes	0,05			
Lyonsiella abyssicola	Mollusca	Bivalvia	quasipoisson	none					none				
Macoma balthica	Mollusca	Bivalvia	poisson	none					none				
Macoma moesta	Mollusca	Bivalvia	poisson	yes	-0,001				yes	-0,01			
Macrobiotus richtersi	Tardigrada	Eutardigrada	quasipoisson	yes				0,001	yes				0,001
Madrepora oculata	Cnidaria	Anthozoa	quasipoisson	yes	0,001				yes	0,001			
Mancikellia divae	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Margarites helicinus	Mollusca	Gastropoda	quasipoisson	none					none				
Margarites olivaceus	Mollusca	Gastropoda	quasipoisson	none					none				
Margaritifera margaritifera	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Mendicula ferruginosa	Mollusca	Bivalvia	quasipoisson	none					none				
Mendicula pygmaea	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Metzgeria alba	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Modeeria rotunda	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Modiolula phaseolina	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Moelleria costulata	Mollusca	Gastropoda	quasipoisson	none					none				
Mohnia mohni	Mollusca	Gastropoda	poisson	none					none				
Mohnia parva	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Montacuta substriata	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Musculus discors	Mollusca	Bivalvia	quasipoisson	none					none				
Musculus niger	Mollusca	Bivalvia	quasipoisson	yes	-0,05				none				
Mya arenaria	Mollusca	Bivalvia	quasipoisson	yes	0,001			0,001	yes	0,001			0,001
Myriotrochus rinkii	Echinodermata	Holothuroidea	quasipoisson	yes			0,001		yes			0,001	
Myriotrochus theeli	Echinodermata	Holothuroidea	quasipoisson	yes				0,001	yes				0,001
Myriotrochus vitreus	Echinodermata	Holothuroidea	quasipoisson	yes				0,001	yes				0,001
Mytilus edulis	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
Nephasoma lilljeborgii	Annelida		quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Neptunea antiqua	Mollusca	Gastropoda	poisson	yes	-0,01				none				
Nucella lapillus	Mollusca	Gastropoda	poisson	yes		-0,05		-0,001	yes				0,001
Nucula nucleus	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Nucula tumidula	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Nuculana minuta	Mollusca	Bivalvia	poisson	yes	-0,001		-0,01	-0,001	yes		0,10		0,001
Obelia dichotoma	Cnidaria	Hydrozoa	quasipoisson	yes				0,001	yes				0,001
Obelia longissima	Cnidaria	Hydrozoa	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Odostomia unidentata	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes		0,001		
Oenopota cinerea	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Oenopota elegans	Mollusca	Gastropoda	quasipoisson	none					none				
Oenopota pyramidalis	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Oenopota tenuicostata	Mollusca	Gastropoda	quasipoisson	none					none				
Onchidoris muricata	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Onchnesoma squamatum	Annelida		quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Onchnesoma steenstrupii	Annelida		quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Onoba aculeus	Mollusca	Gastropoda	poisson	none					none				
Onoba semicostata	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Ophiacantha abyssicola	Echinodermata	Ophiuroidea	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Ophiacantha bidentata	Echinodermata	Ophiuroidea	quasipoisson	yes			-0,05	-0,05	none				
Ophiactis abyssicola	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Ophiocten affinis	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Ophiocten gracilis	Echinodermata	Ophiuroidea	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Ophiocten sericeum	Echinodermata	Ophiuroidea	quasipoisson	yes			-0,05		none				
Ophiolycus purpureus	Echinodermata	Ophiuroidea	quasipoisson	yes	0,001			0,001	yes	0,001			0,001
Ophiopholis aculeata	Echinodermata	Ophiuroidea	quasipoisson	yes	-0,05	-0,05	-0,01	-0,001	yes		-0,1	-0,1	
Ophiopleura borealis	Echinodermata	Ophiuroidea	quasipoisson	none					none				
Ophiopus arcticus	Echinodermata	Ophiuroidea	quasipoisson	none					none				
Ophioscolex glacialis	Echinodermata	Ophiuroidea	quasipoisson	yes			-0,05	-0,05	none				
Ophiura albida	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Ophiura carnea	Echinodermata	Ophiuroidea	quasipoisson	yes				0,001	yes				0,001
Ophiura robusta	Echinodermata	Ophiuroidea	quasipoisson	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
Palliolum striatum	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Palliolum tigerinum	Mollusca	Bivalvia	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Pandora glacialis	Mollusca	Bivalvia	poisson	none					none				
Papillicardium minimum	Mollusca	Bivalvia	quasipoisson	none					none				
Paracuaria adunca	Nematoda	Chromadorea	quasipoisson	yes			0,001		yes			0,001	
Paragorgia arborea	Cnidaria	Anthozoa	quasipoisson	yes	0,001				yes	0,001			
Parastichopus tremulus	Echinodermata	Holothuroidea	quasipoisson	yes				0,001	yes				0,001
Parathyasira dunbari	Mollusca	Bivalvia	quasipoisson	none					none				
Parathyasira equalis	Mollusca	Bivalvia	quasipoisson	none					yes				0,10
Parathyasira granulosa	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Parvicardium pinnulatum	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Patella pellucida	Mollusca	Gastropoda	quasipoisson	yes	0,001				yes	0,001			
Patella vulgata	Mollusca	Gastropoda	quasipoisson	yes	0,001			0,001	yes	0,001			0,001
Pecten maximus	Mollusca	Bivalvia	quasipoisson	yes			0,001		yes			0,001	
Peregriana peregra	Mollusca	Gastropoda	quasipoisson	yes	-0,001	0	-0,001	-0,001	yes	0,001	0,001	-0,001	-0,001
Phakellia ventilabrum	Porifera	Demospongiae	quasipoisson	yes				0,001	yes				0,001
Phascolion strombus	Annelida		quasipoisson	none					none				
Plehnia arctica	Platyhelminthes		poisson	none					none				
Pleurobrachia pileus	Ctenophora	Tentaculata	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Plicifusus kroyeri	Mollusca	Gastropoda	poisson	none					none				
Plotocnide borealis	Cnidaria	Hydrozoa	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Pododesmus patelliformis	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Policordia jeffreysi	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Poliometra prolixa	Echinodermata	Crinoidea	quasipoisson	yes			0,001		yes			0,001	
Polycarpa fibrosa	Chordata	Ascidiacea	quasipoisson	yes				0,001	yes				0,001
Polymastia mamillaris	Porifera	Demospongiae	quasipoisson	yes			0,001		yes			0,001	
Poromya granulata	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Portlandia arctica	Mollusca	Bivalvia	quasipoisson	none					none				
Praephiline finmarchica	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Priapulopsis bicaudatus	Priapulida		quasipoisson	none					none				
Primnoa resedaeformis	Cnidaria	Anthozoa	quasipoisson	yes	0,001				yes	0,001			
Propebela exarata	Mollusca	Gastropoda	quasipoisson	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
Propebela harpularia	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Pseudarchaster parelii	Echinodermata	Asteroidea	quasipoisson	yes				0,001	yes				0,001
Pteraster militaris	Echinodermata	Asteroidea	poisson	yes	-0,05			-0,001	yes	0,10			-0,05
Ptychogastria polaris	Cnidaria	Hydrozoa	quasipoisson	none					none				
Ptychogena crocea	Cnidaria	Hydrozoa	quasipoisson	none					none				
Pulsellum affine	Mollusca	Scaphopoda	quasipoisson	yes				0,001	yes				0,001
Pulsellum lofotense	Mollusca	Scaphopoda	quasipoisson	yes		0,001		0,001	yes		0,001		0,001
Punctulum wyvillethomsoni	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Puncturella noachina	Mollusca	Gastropoda	quasipoisson	yes				-0,05	none				
Pusillina inconspicua	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Pycnanthus densus	Cnidaria	Anthozoa	quasipoisson	none					none				
Radiella sol	Porifera	Demospongiae	quasipoisson	none					none				
Retifusus latericeus	Mollusca	Gastropoda	quasipoisson	none					none				
Rhizocaulus verticillatus	Cnidaria	Hydrozoa	quasipoisson	none					none				
Rhizocrinus lofotensis	Echinodermata	Crinoidea	poisson	none					yes			0,05	
Rissoa parva	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001		yes	0,001	0,001	0,001	
Sarsia tubulosa	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Scaphander lignarius	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Scaphander punctostriatus	Mollusca	Gastropoda	quasipoisson	none					none				
Serripes groenlandicus	Mollusca	Bivalvia	quasipoisson	yes			-0,05	-0,01	yes		-0,05	-0,05	-0,05
Sertularella tenella	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Sertularia tenera	Cnidaria	Hydrozoa	poisson	none					none				
Similipecten similis	Mollusca	Bivalvia	quasipoisson	none					none				
Siphonodentalium laubieri	Mollusca	Scaphopoda	quasipoisson	yes				0,001	yes				0,001
Siphonodentalium lobatum	Mollusca	Scaphopoda	quasipoisson	none					none				
Skenea basistriata	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Skeneopsis planorbis	Mollusca	Gastropoda	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Solariella obscura	Mollusca	Gastropoda	quasipoisson	none					none				
Spatangus purpureus	Echinodermata	Echinoidea	quasipoisson	yes				0,001	yes				0,001
Spatangus raschi	Echinodermata	Echinoidea	quasipoisson	yes				0,001	yes				0,001
Spirotropis monterosatoi	Mollusca	Gastropoda	quasipoisson	yes				0,001	yes				0,001
Spisula elliptica	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**
Stagnicola palustris	Mollusca	Gastropoda	poisson	none					none				
Staurostoma mertensii	Cnidaria	Hydrozoa	quasipoisson	yes			0,001		yes			0,001	
Stegophiura nodosa	Echinodermata	Ophiuroidea	poisson	yes	-0,001				yes	0,001			
Stenosemus albus	Mollusca	Polyplacophora	quasipoisson	none					none				
Steromphala cineraria	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Steromphala tumida	Mollusca	Gastropoda	quasipoisson	none					none				
Symplectoscyphus tricuspidat	Cnidaria	Hydrozoa	poisson	yes	-0,01				none				
Synoicum turgens	Chordata	Ascidiacea	quasipoisson	yes		0,001			yes		0,001		
Tachyrhynchus erosus	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Tachyrhynchus reticulatus	Mollusca	Gastropoda	poisson	none					none				
Taranis moerchii	Mollusca	Gastropoda	quasipoisson	yes		0,001	0,001		yes		0,001	0,001	
Tectura virginea	Mollusca	Gastropoda	poisson	yes	0,001	0,05	-0,05	-0,001	yes	0,001	0,001	0,10	0,05
Tellimya ferruginosa	Mollusca	Bivalvia	quasipoisson	yes			0,001	0,001	yes			0,001	0,001
Testudinalia testudinalis	Mollusca	Gastropoda	poisson	yes	0,001		-0,1	-0,001	yes	0,001	0,05	0,001	
Thenea abyssorum	Porifera	Demospongiae	quasipoisson	yes			0,001		yes			0,001	
Thesbia nana	Mollusca	Gastropoda	quasipoisson	none					none				
Thracia devexa	Mollusca	Bivalvia	poisson	yes				-0,001	none				
Thracia myopsis	Mollusca	Bivalvia	quasipoisson	yes			-0,05	-0,1	yes	0,001			
Thyasira flexuosa	Mollusca	Bivalvia	quasipoisson	none					none				
Thyasira gouldii	Mollusca	Bivalvia	quasipoisson	none					none				
Thyasira obsoleta	Mollusca	Bivalvia	quasipoisson	none					none				
Thyasira sarsii	Mollusca	Bivalvia	quasipoisson	none					none				
Timoclea ovata	Mollusca	Bivalvia	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Tonicella marmorea	Mollusca	Polyplacophora	quasipoisson	none					none				
Tremaster mirabilis	Echinodermata	Asteroidea	quasipoisson	yes			0,001		yes			0,001	
Tritia incrassata	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Trophonopsis barvicensis	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001	0,001	0,001	yes	0,001	0,001	0,001	0,001
Turrisipho voeringi	Mollusca	Gastropoda	quasipoisson	yes			0,001		yes			0,001	
Turtonia minuta	Mollusca	Bivalvia	quasipoisson	yes	0,001		0,001	0,001	yes	0,001		0,001	0,001
Urticina felina	Cnidaria	Anthozoa	quasipoisson	yes	0,001				yes	0,001			
Valvata piscinalis	Mollusca	Gastropoda	poisson	none					none				
Varicorbula gibba	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**
Vitreolina philippi	Mollusca	Gastropoda	quasipoisson	yes		0,001			yes		0,001		
Vitrina pellucida	Mollusca	Gastropoda	quasipoisson	yes	0,001	0,001			yes	0,001	0,001		
Yoldiella annenkovae	Mollusca	Bivalvia	quasipoisson	yes				0,001	yes				0,001
Yoldiella frigida	Mollusca	Bivalvia	quasipoisson	yes			-0,1	0,05	yes	0,05		-0,05	-0,1
Yoldiella intermedia	Mollusca	Bivalvia	poisson	none					yes			0,05	
Yoldiella lenticula	Mollusca	Bivalvia	poisson	yes	0,001	0,05			yes	0,001	0,001	0,001	0,001
Yoldiella lucida	Mollusca	Bivalvia	quasipoisson	none					none				
Yoldiella nana	Mollusca	Bivalvia	quasipoisson	none					none				
Yoldiella philippiana	Mollusca	Bivalvia	quasipoisson	yes		0,001	0,001	0,001	yes		0,001	0,001	0,001
Yoldiella propinqua	Mollusca	Bivalvia	quasipoisson	none					none				
Yoldiella solidula	Mollusca	Bivalvia	quasipoisson	none					none				
Ziminella salmonacea	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
Abra longicallus									128	0.378%
Abra nitida					26	0.450%	39	0.277%	62	0.183%
Abra prismatica									15	0.044%
Acanthocardia echinata									28	0.083%
Acanthotrochus mirabilis							19	0.135%	12	0.035%
Aclis sarsi									11	0.032%
Admete viridula			13	0.119%	59	1.022%	54	0.384%	26	0.077%
Adontorhina similis					23	0.398%	19	0.135%	293	0.865%
Aeginopsis laurentii			15	0.137%	146	2.529%	312	2.219%	288	0.851%
Aeolidia papillosa			13	0.119%						
Aglantha digitale			62	0.567%	102	1.767%	594	4.224%	716	2.115%
Akera bullata			23	0.210%						
Allantactis parasitica	12	0.275%			12	0.208%	24	0.171%		
Alvania cimicoides					23	0.398%				
Alvania punctura					20	0.347%				
Alvania subsoluta									14	0.041%
Amauropsis islandica			26	0.238%			13	0.092%		
Amphilepis norvegica									16	0.047%
Amphipholis squamata							111	0.789%	1105	3.264%
Amphiura borealis							25	0.178%	294	0.868%
Amphiura filiformis									21	0.062%
Amphiura securigera							18	0.128%		
Anatoma crispata					41	0.710%	21	0.149%	24	0.071%
Antalis agilis							19	0.135%	36	0.106%
Antalis entalis					45	0.780%	76	0.540%	347	1.025%
Antalis occidentalis							48	0.341%	316	0.933%
Aplysilla sulfurea									131	0.387%
Aporrhais pespelecani			24	0.220%	32	0.554%	15	0.107%	12	0.035%
Arctica islandica	11	0.252%	32	0.293%	16	0.277%	36	0.256%	54	0.160%
Ariadnaria borealis			88	0.805%	22	0.381%	15	0.107%	37	0.109%
Arianta arbustorum			13	0.119%						
Arion fuscus			15	0.137%						
Ascidia obliqua					12	0.208%				
Astarte crenata	30	0.688%	14	0.128%	50	0.866%	104	0.740%	111	0.328%
Astarte elliptica	58	1.330%	31	0.284%	27	0.468%	46	0.327%	68	0.201%
Astarte montagui	89	2.040%	60	0.549%	42	0.728%	78	0.555%	63	0.186%
Astarte sulcata					51	0.884%	128	0.910%	911	2.691%
Asterias rubens									31	0.092%
Astyris rosacea			13	0.119%	13	0.225%				
Aulactinia stella			17	0.156%						
Aurelia aurita							290	2.062%	29	0.086%
Axinopsida orbiculata	22	0.504%	11	0.101%			28	0.199%	15	0.044%
Axinulus croulinensis					12	0.208%			47	0.139%
Bathyarca frielei							11	0.078%	21	0.062%
Bathyarca pectunculoides			22	0.201%	27	0.468%	227	1.614%	1098	3.243%
Bathycrinus carpenterii							55	0.391%	23	0.068%
Bathyomphalus contortus					16	0.277%				
Bathypolypus arcticus							24	0.171%		
Beroe cucumis			12	0.110%	35	0.606%	72	0.512%	43	0.127%
Bolinopsis infundibulum					32	0.554%				
Boltenia echinata					26	0.450%				
Boreacola maltzani							13	0.092%		
Boreochiton ruber	11	0.252%	117	1.070%	55	0.953%				
Boreotrophon clathratus			100	0.915%	40	0.693%	24	0.171%	21	0.062%
Boreotrophon clavatus									15	0.044%
Boreotrophon truncatus			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
Botrylloides aureus			12	0.110%	16	0.277%				
Bougainvillia superciliaris							14	0.100%	30	0.089%
Brattegardia nanseni			30	0.274%						
Brisaster fragilis									32	0.095%
Brissopsis lyrifera									14	0.041%
Buccinum cyaneum			79	0.723%	11	0.191%				
Buccinum finmarkianum			16	0.146%						
Cactosoma abyssorum							24	0.171%		
Cadulus jeffreysi									20	0.059%
Cadulus propinquus									244	0.721%
Cadulus subfusiformis									13	0.038%
Calliostoma occidentale			24	0.220%					19	0.056%
Calycella syringa			17	0.156%						
Campanularia volubilis	12	0.275%	20	0.183%						
Capulus ungaricus					13	0.225%			15	0.044%
Cardiomya cadiziana									34	0.100%
Ceramaster granularis							25	0.178%	29	0.086%
Cerastoderma edule			12	0.110%	16	0.277%				
Cerithiella metula					14	0.243%	16	0.114%	41	0.121%
Chaetoderma nitidulum					15	0.260%				
Chamelea striatula			26	0.238%			11	0.078%	14	0.041%
Cladorhiza gelida							24	0.171%		
Clausilia bidentata			16	0.146%						
Clelandella miliaris					22	0.381%				
Clione limacina			39	0.357%	73	1.265%	177	1.259%	165	0.487%
Colus gracilis			23	0.210%	14	0.243%	12	0.085%	22	0.065%
Coryphella verrucosa			12	0.110%						
Crenella decussata					58	1.005%	73	0.519%	110	0.325%
Crossaster papposus	87	1.994%	77	0.704%					23	0.068%
Ctenodiscus crispatus							28	0.199%	25	0.074%
Curtitoma trevelliana					40	0.693%	41	0.292%		
Curtitoma violacea					11	0.191%	13	0.092%		
Cuspidaria lamellosa					14	0.243%	113	0.804%	760	2.245%
Cuspidaria obesa							46	0.327%	159	0.470%
Cuspidaria subtorta			12	0.110%			36	0.256%	33	0.097%
Cyanea capillata							280	1.991%	24	0.071%
Cyclopecten hoskynsi	26	0.596%	83	0.759%	30	0.520%	68	0.484%	556	1.642%
Cylista splendens							24	0.171%		
Cyrillia aequalis					12	0.208%				
Cyrillia linearis					25	0.433%				
Dacrydium ockelmanni							103	0.732%	893	2.638%
Dacrydium vitreum	76	1.742%	216	1.976%	93	1.611%	80	0.569%	649	1.917%
Delectopecten vitreus			21	0.192%	11	0.191%	32	0.228%	153	0.452%
Dendrodoa aggregata					19	0.329%				
Dendrodoa grossularia					16	0.277%				
Dendronotus frondosus			28	0.256%			20	0.142%	14	0.041%
Desmophyllum pertusum			75	0.686%						
Diaphana hiemalis									14	0.041%
Didemnum albidum					12	0.208%				
Dimophyes arctica			19	0.174%						
Diplodonta torelli	18	0.413%								
Doto coronata			14	0.128%						
Echinocardium flavescens									18	0.053%
Echinocyamus pusillus									25	0.074%
Echinus esculentus									134	0.396%
Elpidia belyaevi							14	0.100%		

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

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

SPECIES	<1900		1900-1950		1950-1980		1980-2000		2000-2010	
	N	R	N	R	N	R	N	R	N	R
Myriotrochus vitreus									22	0.065%
Mytilus edulis			138	1.262%	11	0.191%	891	6.336%	192	0.567%
Nephasoma lilljeborgii							19	0.135%	23	0.068%
Neptunea antiqua	21	0.481%	12	0.110%	17	0.295%				
Nucella lapillus	15	0.344%	177	1.619%	16	0.277%	748	5.319%	80	0.236%
Nucula nucleus					19	0.329%			34	0.100%
Nucula tumidula					12	0.208%	57	0.405%	198	0.585%
Nuculana minuta	18	0.413%	12	0.110%	31	0.537%	25	0.178%	52	0.154%
Obelia dichotoma									77	0.227%
Obelia longissima							15	0.107%		
Odostomia unidentata					17	0.295%				
Oenopota cinerea							25	0.178%		
Oenopota elegans					22	0.381%	16	0.114%		
Oenopota pyramidalis							28	0.199%		
Oenopota tenuicostata					20	0.347%	22	0.156%	30	0.089%
Onchidoris muricata			18	0.165%						
Onchnesoma squamatum							91	0.647%	237	0.700%
Onchnesoma steenstrupii							58	0.412%	168	0.496%
Onoba aculeus			120	1.098%			17	0.121%	11	0.032%
Onoba semicostata					28	0.485%	19	0.135%		
Ophiacantha abyssicola			13	0.119%			48	0.341%	142	0.419%
Ophiacantha bidentata	420	9.629%	633	5.791%	78	1.351%	59	0.420%	178	0.526%
Ophiactis abyssicola									21	0.062%
Ophiocten affinis									1131	3.341%
Ophiocten gracilis							17	0.121%	136	0.402%
Ophiocten sericeum	137	3.141%	419	3.833%	68	1.178%	59	0.420%	98	0.289%
Ophiolycus purpureus			13	0.119%					27	0.080%
Ophiopholis aculeata	418	9.583%	444	4.062%	48	0.832%	53	0.377%	263	0.777%
Ophiopleura borealis			103	0.942%	48	0.832%	24	0.171%	36	0.106%
Ophiopus arcticus			42	0.384%	13	0.225%	36	0.256%	24	0.071%
Ophioscolex glacialis	85	1.949%	138	1.262%	26	0.450%	29	0.206%	57	0.168%
Ophiura albida									29	0.086%
Ophiura carnea									55	0.162%
Ophiura robusta	247	5.663%	420	3.842%	33	0.572%	66	0.469%	258	0.762%
Palliolum striatum					16	0.277%			18	0.053%
Palliolum tigerinum					11	0.191%			11	0.032%
Pandora glacialis	21	0.481%								
Papillicardium minimum					40	0.693%	61	0.434%	1113	3.288%
Paracuaria adunca							12	0.085%		
Paragorgia arborea			12	0.110%						
Parastichopus tremulus									46	0.136%
Parathyasira dunbari							38	0.270%	260	0.768%
Parathyasira equalis	47	1.077%	119	1.089%	39	0.676%	65	0.462%	279	0.824%
Parathyasira granulosa									32	0.095%
Parvicardium pinnulatum					44	0.762%	41	0.292%	85	0.251%
Patella pellucida			32	0.293%						
Patella vulgata			24	0.220%					18	0.053%
Pecten maximus							138	0.981%		
Peregriana peregra	19	0.436%	21	0.192%	133	2.304%	17	0.121%	12	0.035%
Phakellia ventilabrum									133	0.393%
Phascolion strombus							53	0.377%	160	0.473%
Plehnia arctica	81	1.857%								
Pleurobrachia pileus					11	0.191%	24	0.171%		
Plicifusus kroyeri	19	0.436%								
Plotocnide borealis					38	0.658%	78	0.555%	93	0.275%
Pododesmus patelliformis					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
Policordia jeffreysi									24	0.071%
Poliometra prolixa							24	0.171%		
Polycarpa fibrosa									451	1.332%
Polymastia mamillaris							24	0.171%		
Poromya granulata							15	0.107%	129	0.381%
Portlandia arctica			21	0.192%			12	0.085%	15	0.044%
Praephiline finmarchica									28	0.083%
Priapulopsis bicaudatus							24	0.171%		
Primnoa resedaeformis			23	0.210%						
Propebela exarata							12	0.085%		
Propebela harpularia					14	0.243%				
Pseudarchaster parelii									18	0.053%
Pteraster militaris	26	0.596%	42	0.384%					13	0.038%
Ptychogastria polaris							24	0.171%		
Ptychogena crocea							24	0.171%		
Pulsellum affine									68	0.201%
Pulsellum lofotense					13	0.225%			25	0.074%
Punctulum wyvillethomsoni									45	0.133%
Puncturella noachina	35	0.802%	128	1.171%	90	1.559%	46	0.327%	94	0.278%
Pusillina inconspicua					18	0.312%	17	0.121%		
Pycnanthus densus							24	0.171%		
Radiella sol							26	0.185%		
Retifusus latericeus							25	0.178%		
Rhizocaulus verticillatus							24	0.171%		
Rhizocrinus lofotensis									16	0.047%
Rissoa parva			16	0.146%	20	0.347%	11	0.078%		
Sarsia tubulosa							18	0.128%		
Scaphander lignarius					14	0.243%	15	0.107%	16	0.047%
Scaphander punctostriatus			34	0.311%	24	0.416%	11	0.078%	54	0.160%
Serripes groenlandicus	78	1.788%	104	0.951%	18	0.312%	18	0.128%	14	0.041%
Sertularella tenella							24	0.171%		
Sertularia tenera	15	0.344%					24	0.171%		
Similipecten similis					35	0.606%	20	0.142%	75	0.222%
Siphonodentalium laubieri									216	0.638%
Siphonodentalium lobatum							98	0.697%	150	0.443%
Skenea basistriata					14	0.243%				
Skeneopsis planorbis			81	0.741%			38	0.270%	17	0.050%
Solariella obscura			16	0.146%			17	0.121%	21	0.062%
Spatangus purpureus									17	0.050%
Spatangus raschi									11	0.032%
Spirotropis monterosatoi									11	0.032%
Spisula elliptica									15	0.044%
Stagnicola palustris	17	0.390%								
Staurostoma mertensii							24	0.171%		
Stegophiura nodosa	169	3.874%	269	2.461%						
Stenosemus albus			113	1.034%	199	3.448%	83	0.590%	47	0.139%
Steromphala cineraria			122	1.116%	37	0.641%	14	0.100%	25	0.074%
Steromphala tumida			54	0.494%	64	1.109%	34	0.242%	28	0.083%
Symplectoscyphus tricuspidatus	19	0.436%	11	0.101%						
Synoicum turgens					23	0.398%				
Tachyrhynchus erosus							26	0.185%		
Tachyrhynchus reticulatus	20	0.459%								
Taranis moerchii					15	0.260%	16	0.114%		
Tectura virginea	11	0.252%	110	1.006%	57	0.988%	22	0.156%	25	0.074%
Tellimya ferruginosa							11	0.078%	26	0.077%
Testudinalia testudinalis	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
Thenea abyssorum							14	0.100%		
Thesbia nana					29	0.502%	12	0.085%	14	0.041%
Thracia devexa	11	0.252%							20	0.059%
Thracia myopsis	80	1.834%	168	1.537%	32	0.554%	54	0.384%	46	0.136%
Thyasira flexuosa					15	0.260%	20	0.142%	44	0.130%
Thyasira gouldii					18	0.312%	41	0.292%	127	0.375%
Thyasira obsoleta					21	0.364%	208	1.479%	1485	4.386%
Thyasira sarsii							43	0.306%	40	0.118%
Timoclea ovata			17	0.156%	20	0.347%	16	0.114%	45	0.133%
Tonicella marmorea	12	0.275%	91	0.832%	141	2.443%	62	0.441%	99	0.292%
Tremaster mirabilis							24	0.171%		
Tritia incrassata					30	0.520%				
Trophonopsis barvicensis			11	0.101%	21	0.364%	14	0.100%	12	0.035%
Turrisipho voeringi							30	0.213%		
Turtonia minuta			27	0.247%			34	0.242%	11	0.032%
Urticina felina			17	0.156%						
Valvata piscinalis	12	0.275%								
Varicorbula gibba					11	0.191%	11	0.078%		
Vitreolina philippi					11	0.191%				
Vitrina pellucida			26	0.238%	13	0.225%				
Yoldiella annenkovae									34	0.100%
Yoldiella frigida	38	0.871%	98	0.897%	21	0.364%	11	0.078%	13	0.038%
Yoldiella intermedia	50	1.146%	324	2.964%	67	1.161%	68	0.484%	33	0.097%
Yoldiella lenticula	25	0.573%	315	2.882%	62	1.074%	109	0.775%	299	0.883%
Yoldiella lucida					35	0.606%	156	1.109%	898	2.653%
Yoldiella nana					38	0.658%	96	0.683%	856	2.529%
Yoldiella philippiana					25	0.433%	28	0.199%	74	0.219%
Yoldiella propinqua							67	0.476%	616	1.820%
Yoldiella solidula			13	0.119%			32	0.228%	465	1.374%
Ziminella salmonacea									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
Abra longicallus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128
Abra nitida	0	0	0	0	0	0	0	0	26	0	0	39	0	0	62
Abra prismatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Acanthocardia echinata	0	0	0	0	0	0	0	0	0	0	0	0	0	2	26
Acanthotrochus mirabilis	0	0	0	0	0	0	0	0	0	0	0	19	0	0	12
Aclis sarsi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Admete viridula	0	0	0	2	0	11	0	3	56	5	24	25	0	7	19
Adontorhina similis	0	0	0	0	0	0	0	0	23	0	0	19	0	0	293
Aeginopsis laurentii	0	0	0	9	5	1	3	15	128	0	0	312	0	0	288
Aeolidia papillosa	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
Aglantha digitale	0	0	0	2	7	53	1	4	97	0	0	594	0	2	714
Akera bullata	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0
Allantactis parasitica	0	11	1	0	0	0	1	11	0	5	18	1	0	0	0
Alvania cimicoides	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0
Alvania punctura	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0
Alvania subsoluta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Amauropsis islandica	0	0	0	0	0	26	0	0	0	0	5	8	0	0	0
Amphilepis norvegica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
Amphipholis squamata	0	0	0	0	0	0	0	0	0	0	0	111	0	0	1105
Amphiura borealis	0	0	0	0	0	0	0	0	0	0	0	25	0	0	294
Amphiura filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
Amphiura securigera	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0
Anatoma crispata	0	0	0	0	0	0	0	0	41	0	4	17	0	0	24
Antalis agilis	0	0	0	0	0	0	0	0	0	0	0	19	0	0	36
Antalis entalis	0	0	0	0	0	0	0	0	45	0	1	75	0	0	347
Antalis occidentalis	0	0	0	0	0	0	0	0	0	0	0	48	0	0	316
Aplysilla sulfurea	0	0	0	0	0	0	0	0	0	0	0	0	0	131	0
Aporrhais pespelecani	0	0	0	0	0	24	0	0	32	0	0	15	0	0	12
Arctica islandica	0	2	9	0	1	31	0	0	16	0	0	36	0	1	53
Ariadnaria borealis	0	0	0	0	0	88	0	0	22	0	1	14	0	1	36
Arianta arbustorum	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
Arion fuscus	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
Ascidia obliqua	0	0	0	0	0	0	0	1	11	0	0	0	0	0	0
Astarte crenata	0	15	15	0	12	2	0	20	30	0	17	87	0	18	93
Astarte elliptica	4	40	14	0	20	11	0	1	26	0	24	22	0	2	66
Astarte montagui	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
Astarte sulcata	0	0	0	0	0	0	0	1	50	0	1	127	0	6	905
Asterias rubens	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
Astyris rosacea	0	0	0	0	1	12	0	0	13	0	0	0	0	0	0
Aulactinia stella	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
Aurelia aurita	0	0	0	0	0	0	0	0	0	0	0	290	0	0	29
Axinopsida orbiculata	0	21	1	0	11	0	0	0	0	0	24	4	0	14	1
Axinulus croulinensis	0	0	0	0	0	0	0	0	12	0	0	0	0	0	47
Bathyarca frielei	0	0	0	0	0	0	0	0	0	0	0	11	0	3	18
Bathyarca pectunculoides	0	0	0	0	1	21	0	0	27	5	18	204	0	2	1096
Bathycrinus carpenterii	0	0	0	0	0	0	0	0	0	6	20	29	1	1	21
Bathyomphalus contortus	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0
Bathypolypus arcticus	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Beroe cucumis	0	0	0	0	2	10	0	1	34	0	0	72	0	0	43
Bolinopsis infundibulum	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0
Boltenia echinata	0	0	0	0	0	0	0	23	3	0	0	0	0	0	0
Boreacola maltzani	0	0	0	0	0	0	0	0	0	0	7	6	0	0	0
Boreochiton ruber	0	0	11	0	1	116	0	4	51	0	0	0	0	0	0
Boreotrophon clathratus	0	0	0	0	2	98	0	0	40	0	5	19	0	0	21
Boreotrophon clavatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Boreotrophon truncatus	0	0	0	0	0	27	0	3	20	5	22	14	0	0	20
Botrylloides aureus	0	0	0	0	0	12	0	10	6	0	0	0	0	0	0
Bougainvillia superciliaris	0	0	0	0	0	0	0	0	0	0	0	14	0	0	30
Brattegardia nanseni	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0
Brisaster fragilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
Brissopsis lyrifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Buccinum cyaneum	0	0	0	2	16	61	0	11	0	0	0	0	0	0	0
Buccinum finmarkianum	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
Cactosoma abyssorum	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Cadulus jeffreysi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
Cadulus propinquus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	244
Cadulus subfusiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Calliostoma occidentale	0	0	0	0	0	24	0	0	0	0	0	0	0	0	19
Calycella syringa	0	0	0	0	14	3	0	0	0	0	0	0	0	0	0
Campanularia volubilis	0	12	0	0	14	6	0	0	0	0	0	0	0	0	0
Capulus ungaricus	0	0	0	0	0	0	0	0	13	0	0	0	0	0	15
Cardiomya cadiziana	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
Ceramaster granularis	0	0	0	0	0	0	0	0	0	5	18	2	0	0	29
Cerastoderma edule	0	0	0	0	0	12	0	0	16	0	0	0	0	0	0
Cerithiella metula	0	0	0	0	0	0	0	0	14	0	0	16	0	1	40
Chaetoderma nitidulum	0	0	0	0	0	0	0	2	13	0	0	0	0	0	0
Chamelea striatula	0	0	0	0	0	26	0	0	0	0	0	11	0	0	14
Cladorhiza gelida	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Clausilia bidentata	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
Clelandella miliaris	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0
Clione limacina	0	0	0	12	17	10	8	6	59	0	9	168	0	2	163
Colus gracilis	0	0	0	0	0	23	0	0	14	0	0	12	0	0	22
Coryphella verrucosa	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
Crenella decussata	0	0	0	0	0	0	0	0	58	0	10	63	0	8	102
Crossaster papposus	1	14	72	30	9	38	0	0	0	0	0	0	0	5	18
Ctenodiscus crispatus	0	0	0	0	0	0	0	0	0	5	18	5	0	2	23
Curtitoma trevelliana	0	0	0	0	0	0	0	0	40	5	19	17	0	0	0
Curtitoma violacea	0	0	0	0	0	0	0	0	11	0	3	10	0	0	0
Cuspidaria lamellosa	0	0	0	0	0	0	0	0	14	0	0	113	0	0	760
Cuspidaria obesa	0	0	0	0	0	0	0	0	0	0	0	46	0	4	155
Cuspidaria subtorta	0	0	0	0	12	0	0	0	0	5	26	5	0	6	27
Cyanea capillata	0	0	0	0	0	0	0	0	0	0	0	280	0	0	24
Cyclopecten hoskynsi	0	5	21	16	38	29	4	1	25	5	18	45	0	0	556
Cylista splendens	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Cyrillia aequalis	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0
Cyrillia linearis	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
Dacrydium ockelmanni	0	0	0	0	0	0	0	0	0	0	0	103	0	0	893
Dacrydium vitreum	2	24	50	44	104	68	5	22	66	5	21	54	0	14	635
Delectopecten vitreus	0	0	0	0	0	21	0	0	11	0	0	32	0	0	153
Dendrodoa aggregata	0	0	0	0	0	0	0	7	12	0	0	0	0	0	0
Dendrodoa grossularia	0	0	0	0	0	0	0	13	3	0	0	0	0	0	0
Dendronotus frondosus	0	0	0	0	3	25	0	0	0	0	20	0	0	6	8
Desmophyllum pertusum	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0
Diaphana hiemalis	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1
Didemnum albidum	0	0	0	0	0	0	0	5	7	0	0	0	0	0	0
Dimophyes arctica	0	0	0	6	3	10	0	0	0	0	0	0	0	0	0
Diplodonta torelli	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0
Doto coronata	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
Echinocardium flavescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Echinocyamus pusillus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Echinus esculentus	0	0	0	0	0	0	0	0	0	0	0	0	0	131	3
Elpidia belyaevi	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0
Elpidia glacialis	0	0	0	0	0	0	0	0	0	7	18	5	0	0	24
Emarginula crassa	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Ennucula convexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Ennucula corticata	0	0	0	0	0	0	0	0	23	0	2	28	0	2	118
Ennucula tenuis	3	45	3	0	42	14	0	7	51	0	62	51	0	45	123
Entalina tetragona	0	0	0	0	0	0	0	0	0	0	0	18	0	0	69
Epizoanthus papillosus	0	0	0	0	0	0	0	0	0	5	18	1	0	0	65
Erginus rubellus	1	9	3	0	0	0	0	0	0	0	11	3	0	0	0
Euconulus fulvus	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0
Eudendrium capillare	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Eudendrium ramosum	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Eulima bilineata	0	0	0	0	0	0	0	0	14	0	0	15	0	0	35
Eulimella scillae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Eumetula arctica	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
Eupyrgus scaber	0	0	0	0	0	0	0	0	0	6	23	3	0	0	0
Euspira montagui	0	0	0	0	0	0	0	0	71	0	0	50	0	0	168
Euspira nitida	0	0	0	0	0	0	0	0	20	0	0	0	0	0	26
Flabellum macandrewi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Frigidoalvania janmayeni	0	0	0	0	0	0	0	0	0	5	27	1	0	0	0
Galba truncatula	0	0	19	0	0	0	0	0	25	0	0	0	0	0	0
Genaxinus eumyarius	0	0	0	0	0	0	0	0	0	0	0	15	0	0	72
Glandulactis spetsbergensis	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Golfingia margaritacea	0	0	0	0	0	0	0	0	0	0	15	31	0	25	7
Golfingia vulgaris	0	0	0	0	0	0	0	0	0	0	36	56	0	51	0
Gorgonocephalus arcticus	0	0	0	22	19	8	0	0	0	0	0	0	0	0	0
Gorgonocephalus eucnemis	0	8	6	31	14	11	6	10	0	0	0	0	0	0	0
Gracilechinus acutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Grammaria abietina	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Gyraulus acronicus	0	0	29	0	0	24	0	0	59	0	0	13	0	0	0
Gyrodactylus albolacustris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Gyrodactylus arcuatus	0	0	0	0	0	0	0	0	0	0	0	16	0	0	55
Halcampa arctica	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
Halecium beanii	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Halecium labrosum	0	12	0	0	0	0	0	0	0	5	18	1	0	0	0
Haliella stenostoma	0	0	0	0	0	21	0	0	0	0	0	23	0	0	64
Halitholus yoldiaearcticae	0	0	0	0	0	0	0	0	0	0	0	30	0	0	24
Halocynthia pyriformis	0	0	0	0	0	0	0	14	3	0	0	0	0	138	0
Hanleya hanleyi	0	0	0	0	0	21	0	0	44	0	0	14	0	0	24
Henricia perforata	0	0	0	0	0	0	0	0	0	0	0	0	0	2	44
Henricia sanguinolenta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56
Hermania scabra	0	0	0	0	0	0	0	0	12	0	0	18	0	0	12
Heteranomia squamula	0	0	0	0	8	56	0	0	12	0	0	33	0	0	429
Hiatella rugosa	0	0	0	0	0	0	0	0	0	0	7	11	0	5	17
Hippasteria phrygiana	0	0	0	0	0	0	0	0	0	5	18	3	0	1	10
Hormathia digitata	0	0	0	0	1	23	0	19	20	5	18	1	0	0	0
Hormathia nodosa	0	17	1	0	0	0	0	0	0	5	18	1	0	0	0
Hydractinia carica	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Hydrallmania falcata	0	0	0	0	6	7	0	0	0	0	0	0	0	0	0
Iothia fulva	0	0	0	0	0	27	0	0	35	0	0	18	0	0	17
Isohypsibius prosostomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Kadosactis rosea	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Karnekampia sulcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159
Kellia suborbicularis	0	0	0	0	0	0	0	0	19	0	0	11	0	0	0
Kelliella miliaris	0	0	0	0	0	0	0	0	12	0	0	18	0	0	82
Kophobelemnon stelliferum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
Korethraster hispidus	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Kurtiella bidentata	0	0	0	0	0	0	0	0	0	0	0	11	0	0	24
Labidoplax buskii	0	0	0	0	0	0	0	0	0	0	0	51	0	0	1144
Lacuna crassior	0	0	0	0	0	0	0	0	0	0	7	7	0	0	0
Lacuna pallidula	0	0	0	0	1	40	0	0	0	0	1	18	0	0	0
Lacuna parva	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0
Lacuna vincta	0	3	10	0	0	72	0	0	88	0	0	56	0	0	25
Laeocochlis sinistrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
Lafoea dumosa	3	11	2	6	7	13	0	44	3	5	18	1	0	0	0
Laona quadrata	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Ledella messanensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Lepeta caeca	2	30	9	0	19	135	0	7	81	0	29	40	0	91	47
Lepidochitona cinerea	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
Leptaxinus minutus	0	0	0	0	0	0	0	0	0	0	0	17	0	0	199
Leptochiton alveolus	0	0	0	0	0	13	0	0	45	0	0	42	0	0	32
Leptochiton arcticus	0	0	12	1	9	61	0	13	46	0	0	0	0	0	16
Leptochiton asellus	0	0	0	0	1	35	0	0	118	0	0	44	0	1	46
Leptychaster arcticus	0	0	0	0	0	0	0	0	0	5	18	4	0	0	49
Limacina helicina	0	0	0	19	25	1	16	9	14	0	32	95	0	0	156
Limacina retroversa	0	0	0	0	0	50	0	0	0	0	0	0	0	1	19
Limatula gwyni	0	0	0	0	0	0	0	0	0	0	0	18	0	0	269
Limatula subauriculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Limea crassa	0	0	0	0	0	0	0	0	0	0	0	22	0	0	125
Limopsis aurita	0	0	0	0	0	0	0	0	0	0	0	59	0	0	34
Limopsis cristata	0	0	0	0	0	0	0	0	0	0	0	60	0	0	541
Limopsis minuta	0	0	0	0	0	0	0	0	0	0	0	75	0	0	133
Liocyma fluctuosa	11	37	2	26	29	3	0	0	0	0	13	0	0	0	0
Littorina littorea	0	0	0	0	0	120	0	0	0	0	0	16	0	0	25
Littorina obtusata	0	0	14	0	0	248	0	0	13	0	0	27	0	0	33
Littorina saxatilis	0	5	30	0	3	257	0	0	25	0	2	35	0	6	46
Lophaster furcifer	1	13	3	15	15	1	0	0	0	5	18	1	0	0	0
Lucinoma borealis	0	0	0	0	0	14	0	0	0	0	0	17	0	0	15
Luidia sarsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Lyonsia arenosa	1	30	20	19	24	36	0	0	0	0	0	0	0	0	0
Lyonsiella abyssicola	0	0	0	0	0	0	0	0	0	0	0	41	0	2	602
Macoma balthica	0	0	0	0	0	38	0	0	0	1	0	23	0	0	16
Macoma moesta	3	33	0	0	15	0	0	0	0	0	0	0	0	0	0
Macrobiotus richtersi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28
Madrepora oculata	0	0	0	0	0	123	0	0	0	0	0	0	0	0	0
Mancikellia divae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31
Margarites helicinus	0	0	0	2	5	130	0	0	39	0	18	26	0	5	22
Margarites olivaceus	0	10	3	0	2	9	0	0	0	0	35	3	0	27	6
Margaritifera margaritifera	0	0	0	0	0	0	0	0	30	0	0	35	0	0	0
Mendicula ferruginosa	0	0	0	0	0	0	0	0	26	0	4	28	0	0	221
Mendicula pygmaea	0	0	0	0	0	0	0	0	0	0	0	73	0	0	46
Metzgeria alba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
Modeeria rotunda	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Modiolula phaseolina	0	0	0	0	0	0	0	0	48	0	0	42	0	0	213
Moelleria costulata	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
Mohnia mohni	0	0	0	0	0	0	0	0	0	0	1	11	0	0	14
Mohnia parva	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Montacuta substriata	0	0	0	0	0	0	0	0	0	0	0	11	0	0	26
Musculus discors	0	0	0	4	1	40	0	0	12	0	15	18	0	7	27
Musculus niger	0	26	8	2	11	6	0	1	30	7	25	37	0	6	39
Mya arenaria	0	0	0	0	0	14	0	0	0	0	0	0	0	0	12
Myriotrochus rinkii	0	0	0	0	0	0	0	0	0	7	18	1	0	0	0
Myriotrochus theeli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Myriotrochus vitreus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Mytilus edulis	0	0	0	2	0	136	0	0	11	0	1	890	1	0	191
Nephasoma lilljeborgii	0	0	0	0	0	0	0	0	0	0	19	0	0	23	0
Neptunea antiqua	0	17	4	0	9	3	0	3	14	0	0	0	0	0	0
Nucella lapillus	0	1	14	0	0	177	0	0	16	0	0	748	0	0	80
Nucula nucleus	0	0	0	0	0	0	0	0	19	0	0	0	0	0	34
Nucula tumidula	0	0	0	0	0	0	0	0	12	0	0	57	0	0	198
Nuculana minuta	0	12	6	0	0	12	0	0	31	0	0	25	0	6	46
Obelia dichotoma	0	0	0	0	0	0	0	0	0	0	0	0	0	77	0
Obelia longissima	0	0	0	0	0	0	0	0	0	0	1	14	0	0	0
Odostomia unidentata	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0
Oenopota cinerea	0	0	0	0	0	0	0	0	0	5	18	2	0	0	0
Oenopota elegans	0	0	0	0	0	0	0	0	22	0	4	12	0	0	0
Oenopota pyramidalis	0	0	0	0	0	0	0	0	0	5	20	3	0	0	0
Oenopota tenuicostata	0	0	0	0	0	0	0	0	20	0	0	22	0	1	29
Onchidoris muricata	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
Onchnesoma squamatum	0	0	0	0	0	0	0	0	0	0	0	91	0	0	237
Onchnesoma steenstrupii	0	0	0	0	0	0	0	0	0	0	0	58	0	0	168
Onoba aculeus	0	0	0	0	0	120	0	0	0	0	1	16	0	0	11
Onoba semicostata	0	0	0	0	0	0	0	0	28	0	0	19	0	0	0
Ophiacantha abyssicola	0	0	0	0	0	13	0	0	0	0	0	48	0	0	142
Ophiacantha bidentata	11	86	323	295	185	153	13	61	4	38	18	3	0	41	137
Ophiactis abyssicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
Ophiocten affinis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1131
Ophiocten gracilis	0	0	0	0	0	0	0	0	0	0	0	17	0	0	136
Ophiocten sericeum	4	71	62	238	125	56	22	44	2	38	18	3	0	21	77
Ophiolycus purpureus	0	0	0	0	0	13	0	0	0	0	0	0	0	0	27
Ophiopholis aculeata	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
Ophiopleura borealis	0	0	0	85	18	0	24	24	0	5	18	1	0	2	34
Ophiopus arcticus	0	0	0	20	22	0	3	7	3	17	18	1	0	0	24
Ophioscolex glacialis	2	24	59	56	56	26	8	13	5	7	18	4	0	1	56
Ophiura albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29
Ophiura carnea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
Ophiura robusta	6	40	201	209	75	136	15	15	3	41	24	1	0	10	248
Palliolum striatum	0	0	0	0	0	0	0	0	16	0	0	0	0	0	18
Palliolum tigerinum	0	0	0	0	0	0	0	0	11	0	0	0	0	0	11
Pandora glacialis	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0
Papillicardium minimum	0	0	0	0	0	0	0	0	40	0	0	61	0	1	1112
Paracuaria adunca	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
Paragorgia arborea	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0
Parastichopus tremulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46
Parathyasira dunbari	0	0	0	0	0	0	0	0	0	0	17	21	0	33	227
Parathyasira equalis	2	10	35	24	46	49	0	3	36	0	4	61	0	0	279
Parathyasira granulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
Parvicardium pinnulatum	0	0	0	0	0	0	0	0	44	0	0	41	0	0	85
Patella pellucida	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0
Patella vulgata	0	0	0	0	0	24	0	0	0	0	0	0	0	0	18
Pecten maximus	0	0	0	0	0	0	0	0	0	0	0	138	0	0	0
Peregriana peregra	0	0	19	0	0	21	0	0	133	0	0	17	0	0	12
Phakellia ventilabrum	0	0	0	0	0	0	0	0	0	0	0	0	0	131	2
Phascolion strombus	0	0	0	0	0	0	0	0	0	5	29	19	0	17	143
Plehnia arctica	0	81	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurobrachia pileus	0	0	0	0	0	0	0	0	11	0	0	24	0	0	0
Plicifusus kroyeri	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0
Plotocnide borealis	0	0	0	0	0	0	0	0	38	0	0	78	0	0	93
Pododesmus patelliformis	0	0	0	0	0	0	0	0	16	0	0	14	0	0	12
Policordia jeffreysi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Poliometra prolixa	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Polycarpa fibrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	451
Polymastia mamillaris	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Poromya granulata	0	0	0	0	0	0	0	0	0	0	0	15	0	0	129
Portlandia arctica	0	0	0	0	21	0	0	0	0	0	10	2	0	9	6
Praephiline finmarchica	0	0	0	0	0	0	0	0	0	0	0	0	0	8	20
Priapulopsis bicaudatus	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0

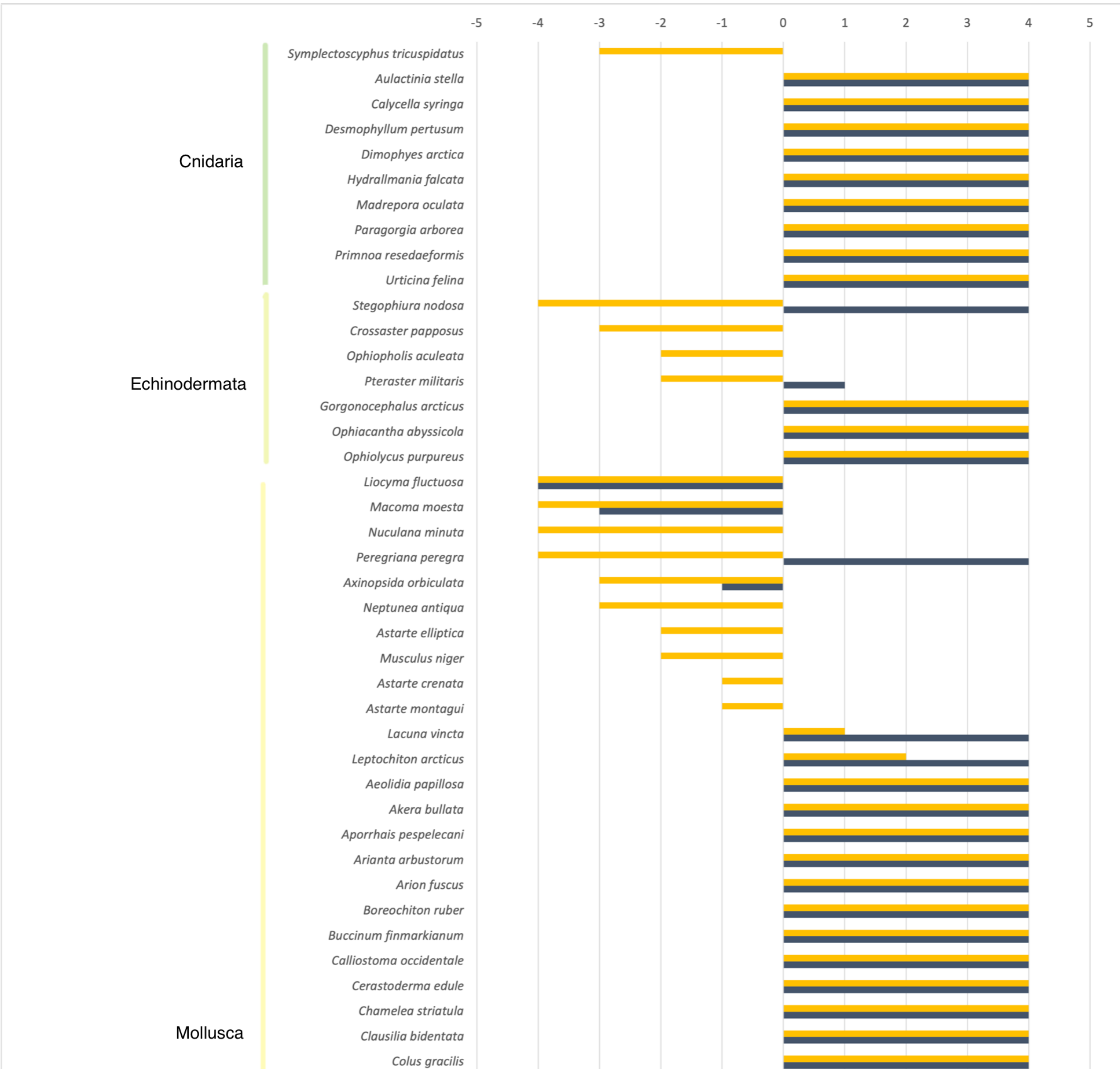
SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
Primnoa resedaeformis	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0
Propebela exarata	0	0	0	0	0	0	0	0	0	0	5	7	0	0	0
Propebela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

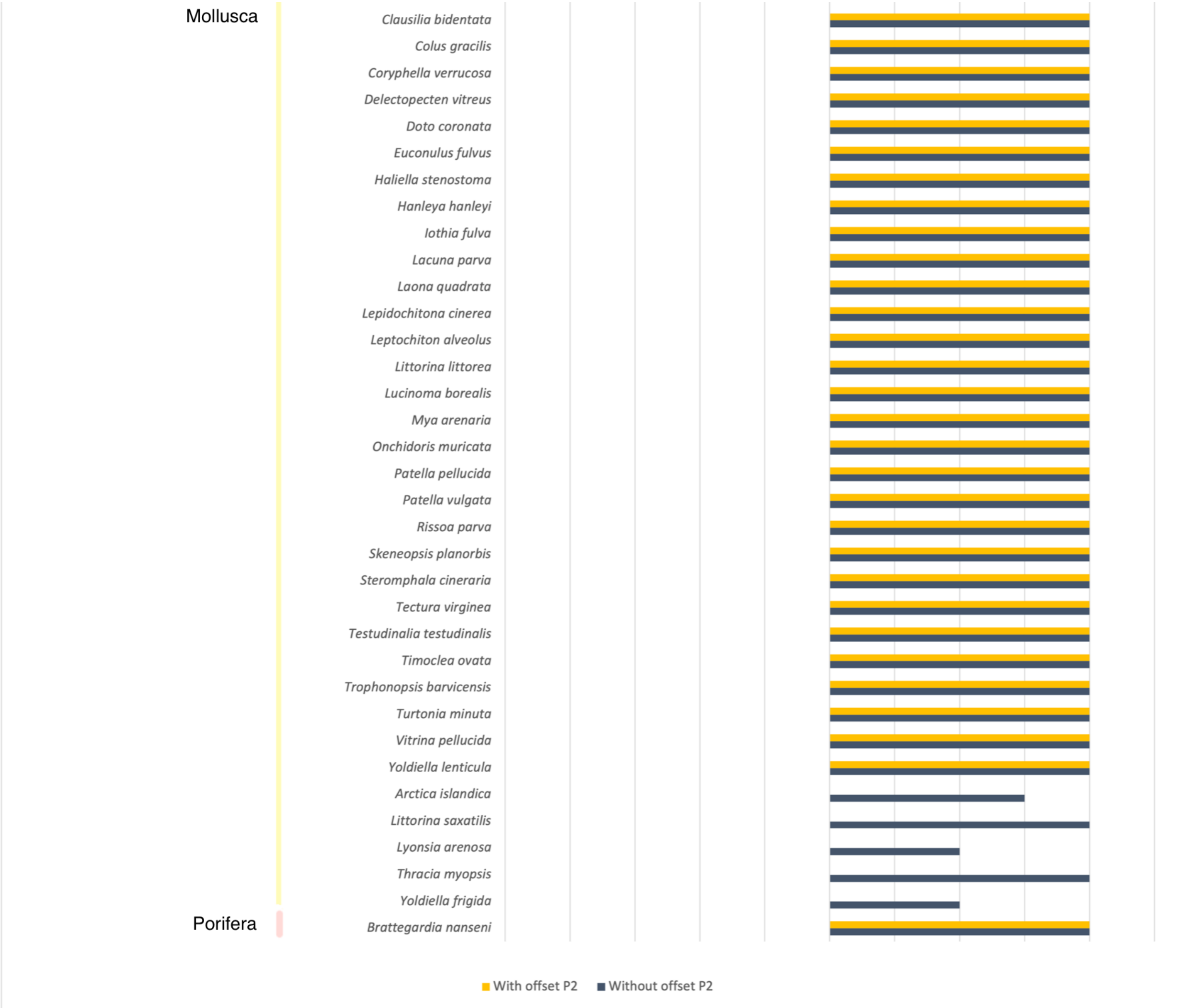
SPECIES	<1900			1900-1950			1950-1980			1980-2000			2000-2010		
	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm	Z1 cold	Z2 mixed	Z3 warm
Stegophiura nodosa	36	35	98	103	32	134	0	0	0	0	0	0	0	0	0
Stenosemus albus	0	0	0	1	6	106	6	70	123	0	18	65	0	17	30
Steromphala cineraria	0	0	0	0	0	122	0	0	37	0	0	14	0	0	25
Steromphala tumida	0	0	0	0	0	54	0	1	63	0	0	34	0	0	28
Symplectoscyphus tricuspidatus	1	16	2	0	2	9	0	0	0	0	0	0	0	0	0
Synoicum turgens	0	0	0	0	0	0	0	11	12	0	0	0	0	0	0
Tachyrhynchus erosus	0	0	0	0	0	0	0	0	0	5	20	1	0	0	0
Tachyrhynchus reticulatus	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0
Taranis moerchii	0	0	0	0	0	0	0	0	15	0	0	16	0	0	0
Tectura virginea	0	1	10	0	0	110	0	0	57	0	0	22	0	0	25
Tellimya ferruginosa	0	0	0	0	0	0	0	0	0	0	0	11	0	0	26
Testudinalia testudinalis	0	0	19	0	0	210	0	0	39	0	0	57	0	0	21
Thenea abyssorum	0	0	0	0	0	0	0	0	0	2	9	3	0	0	0
Thesbia nana	0	0	0	0	0	0	0	0	29	0	1	11	0	0	14
Thracia devexa	0	6	5	0	0	0	0	0	0	0	0	0	0	0	20
Thracia myopsis	1	35	44	12	64	92	5	8	19	5	32	17	0	2	44
Thyasira flexuosa	0	0	0	0	0	0	0	0	15	0	1	19	0	1	43
Thyasira gouldii	0	0	0	0	0	0	0	1	17	0	16	25	0	7	120
Thyasira obsoleta	0	0	0	0	0	0	0	0	21	0	0	208	0	1	1484
Thyasira sarsii	0	0	0	0	0	0	0	0	0	0	16	27	0	0	40
Timoclea ovata	0	0	0	0	0	17	0	0	20	0	0	16	0	0	45
Tonicella marmorea	0	0	12	1	3	87	0	64	77	0	19	43	0	91	8
Tremaster mirabilis	0	0	0	0	0	0	0	0	0	5	18	1	0	0	0
Tritia incrassata	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0
Trophonopsis barvicensis	0	0	0	0	0	11	0	0	21	0	0	14	0	0	12
Turrisipho voeringi	0	0	0	0	0	0	0	0	0	5	18	7	0	0	0
Turtonia minuta	0	0	0	0	0	27	0	0	0	0	0	34	0	0	11
Urticina felina	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0
Valvata piscinalis	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0
Varicorbula gibba	0	0	0	0	0	0	0	0	11	0	0	11	0	0	0
Vitreolina philippi	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0
Vitrina pellucida	0	0	0	0	0	26	0	0	13	0	0	0	0	0	0
Yoldiella annenkovae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32
Yoldiella frigida	2	9	27	0	45	53	0	4	17	0	6	5	0	7	6
Yoldiella intermedia	0	7	43	0	84	240	0	18	49	5	19	44	0	10	23
Yoldiella lenticula	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
Yoldiella lucida	0	0	0	0	0	0	0	2	33	7	20	129	0	10	888
Yoldiella nana	0	0	0	0	0	0	0	0	38	0	3	93	0	8	848
Yoldiella philippiana	0	0	0	0	0	0	0	0	25	0	0	28	0	0	74
Yoldiella propinqua	0	0	0	0	0	0	0	0	0	0	0	67	0	9	607
Yoldiella solidula	0	0	0	0	13	0	0	0	0	0	14	18	0	20	445
Ziminella salmonacea	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

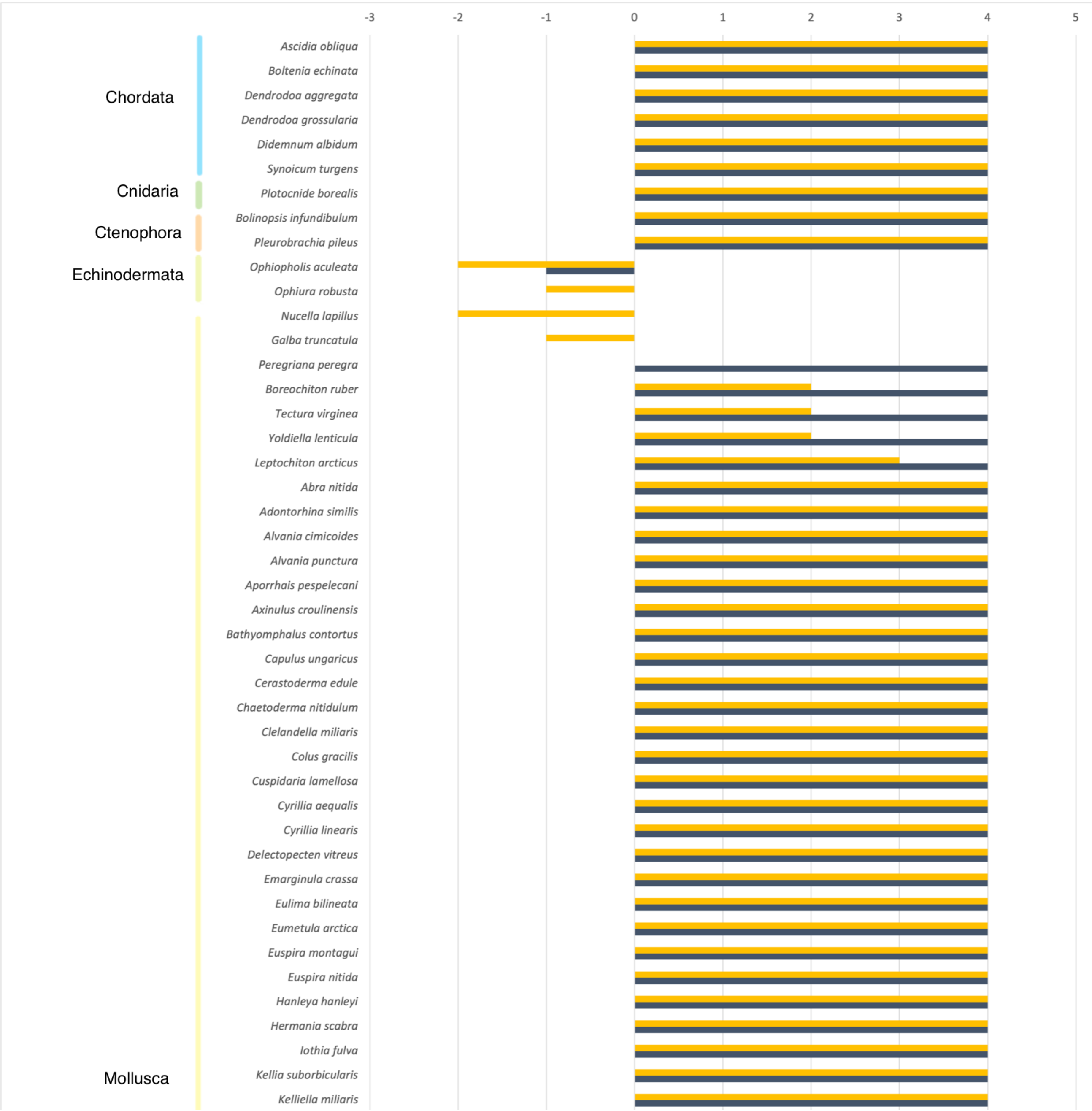




Mollusca
Clausilia bidentata
Colus gracilis
Coryphella verrucosa
Delectopecten vitreus
Doto coronata
Euconulus fulvus
Haliella stenostoma
Hanleya hanleyi
Iothia fulva
Lacuna parva
Laona quadrata
Lepidochitona cinerea
Leptochiton alveolus
Littorina littorea
Lucinoma borealis
Mya arenaria
Onchidoris muricata
Patella pellucida
Patella vulgata
Rissoa parva
Skeneopsis planorbis
Steromphala cineraria
Tectura virginea
Testudinalia testudinalis
Timoclea ovata
Trophonopsis barvicensis
Turtonia minuta
Vitrina pellucida
Yoldiella lenticula
Arctica islandica
Littorina saxatilis
Lyonsia arenosa
Thracia myopsis
Yoldiella frigida
Porifera
Brattegardia nanseni
With offset P2
Without offset P2

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

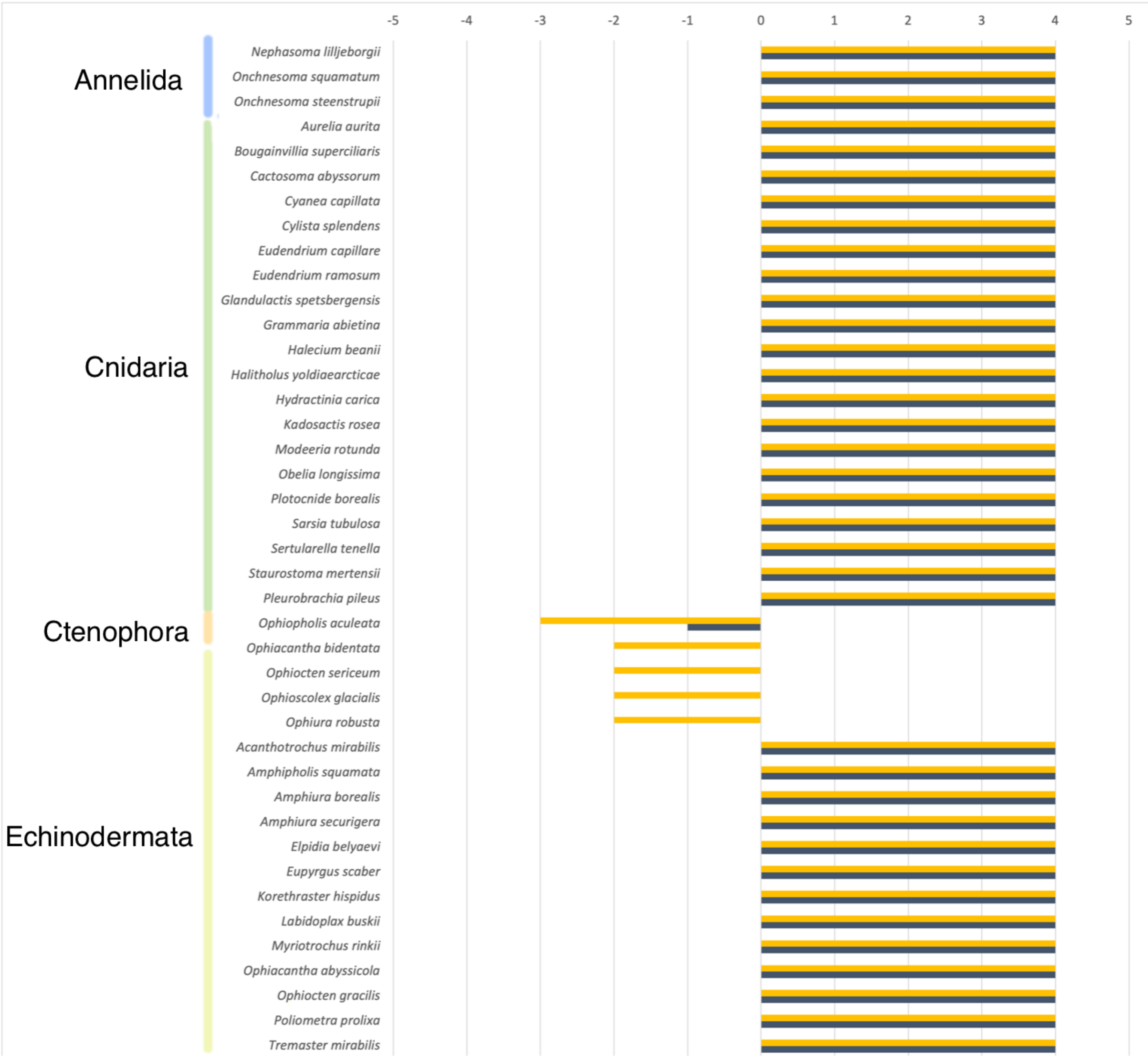
P3: 1950-1980; intercept: P1 before 1900
Species sorted by Phylum.
Significance codes: positive: increase; negative: decrease.
4: p <0.001; 3: p <0.01; 2: p <0.05; 1: p <0.1
Yellow is with offset, blue is without offset

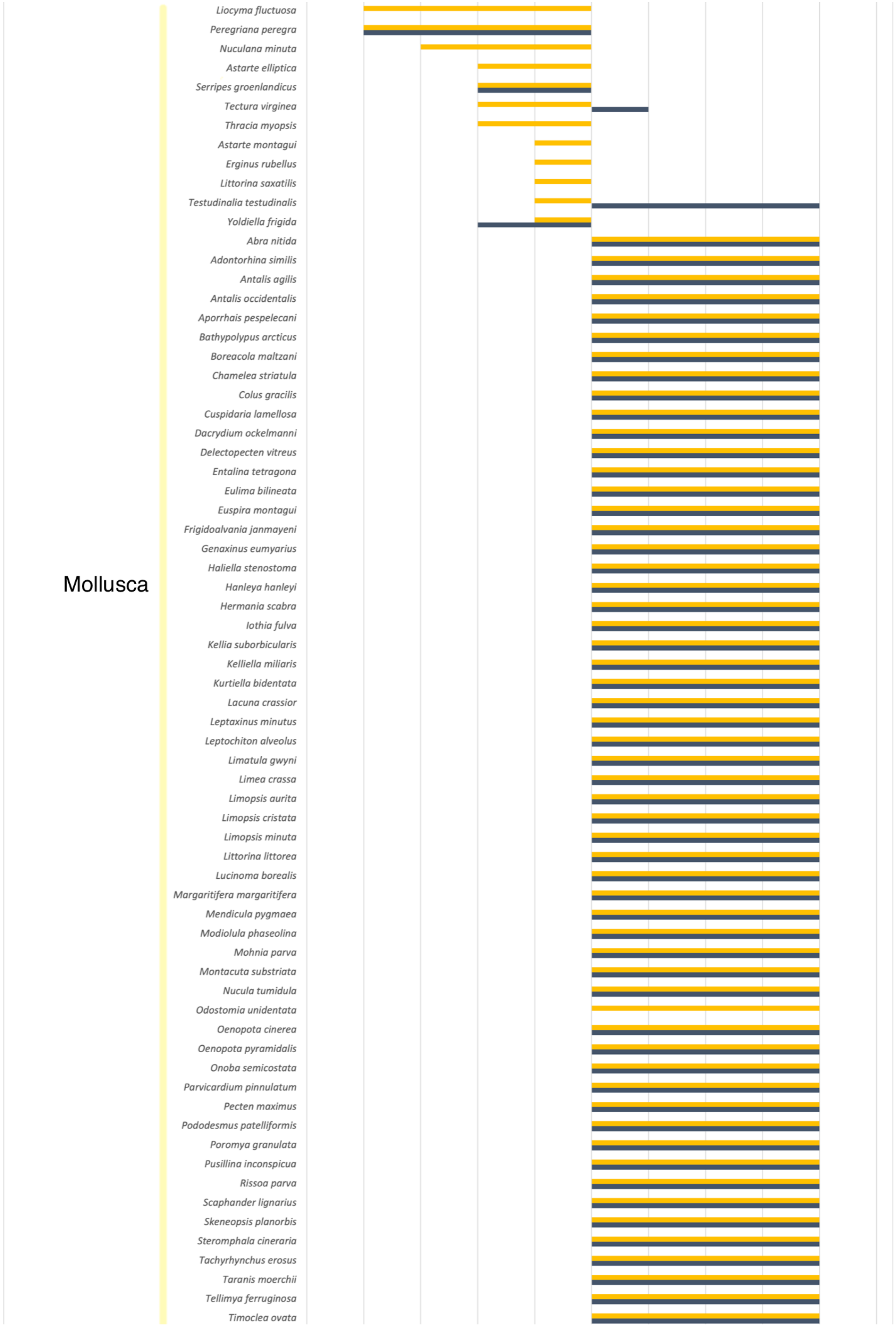


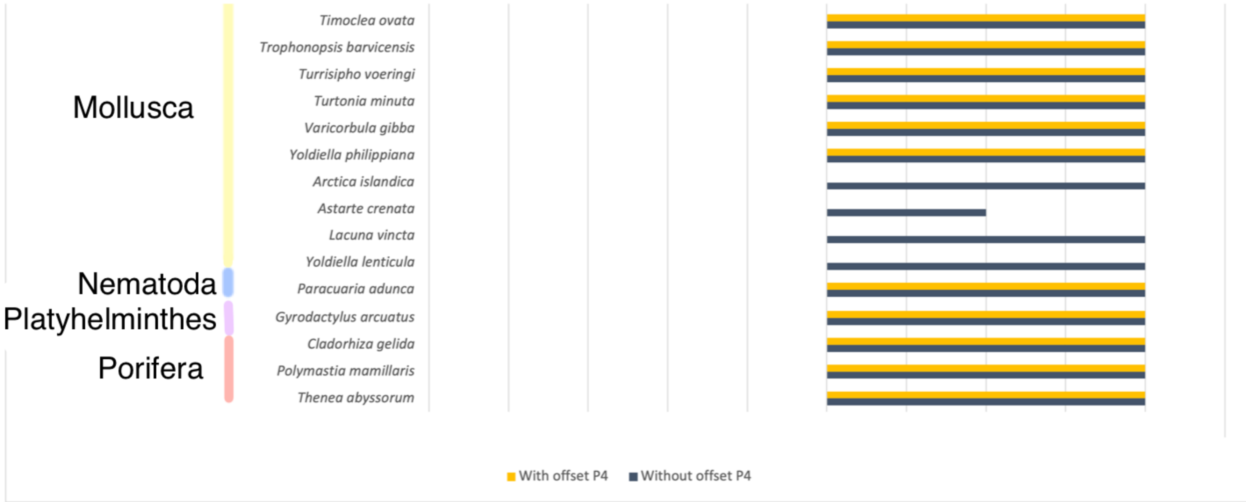
Mollusca
Kellia suborbicularis
Kelliella miliaris
Lacuna vincta
Leptochiton alveolus
Margaritifera margaritifera
Modiolula phaseolina
Nucula nucleus
Nucula tumidula
Onoba semicostata
Palliolum striatum
Palliolum tigerinum
Parvicardium pinnulatum
Pododesmus patelliformis
Propebela harpularia
Pulsellum 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

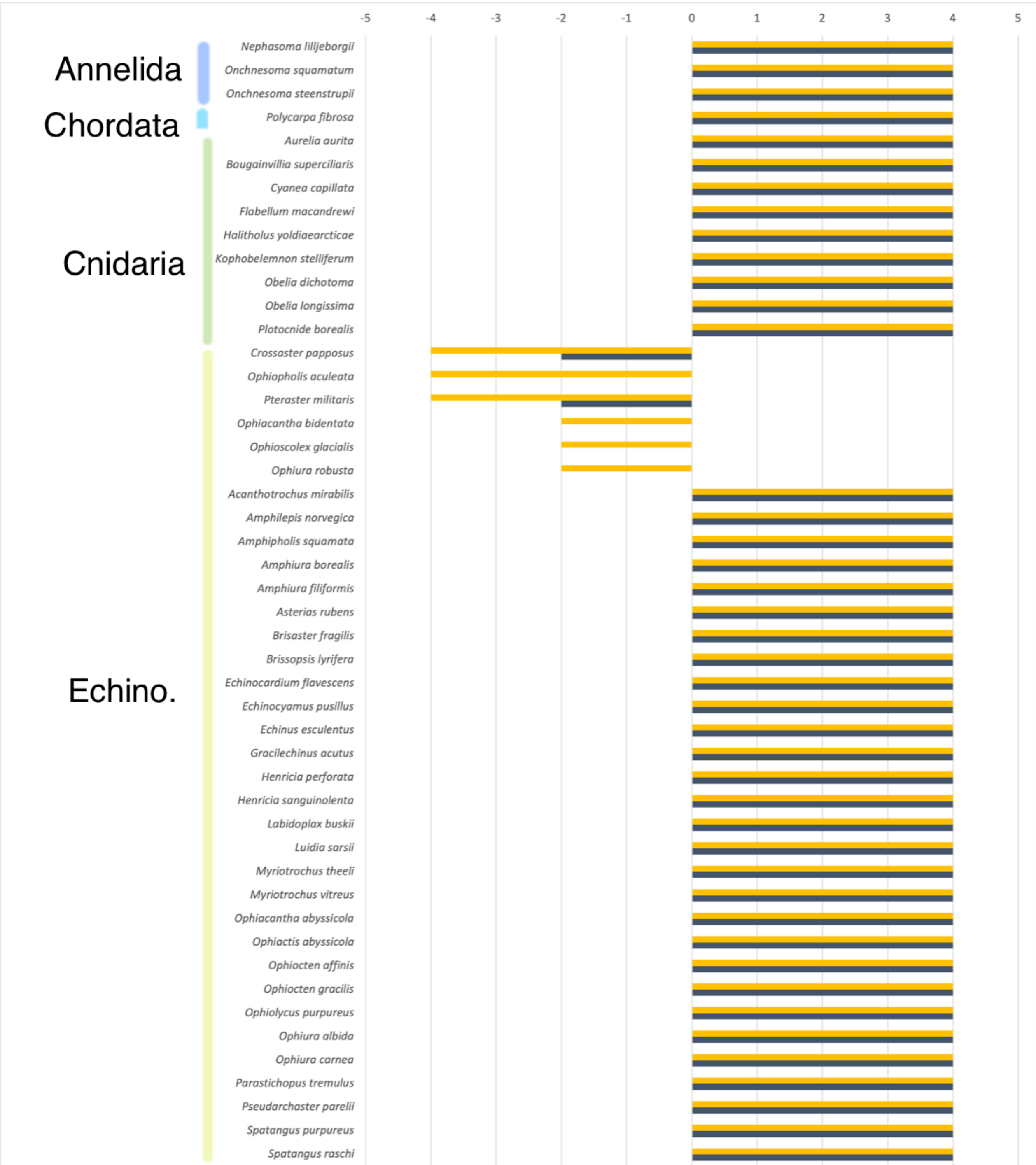


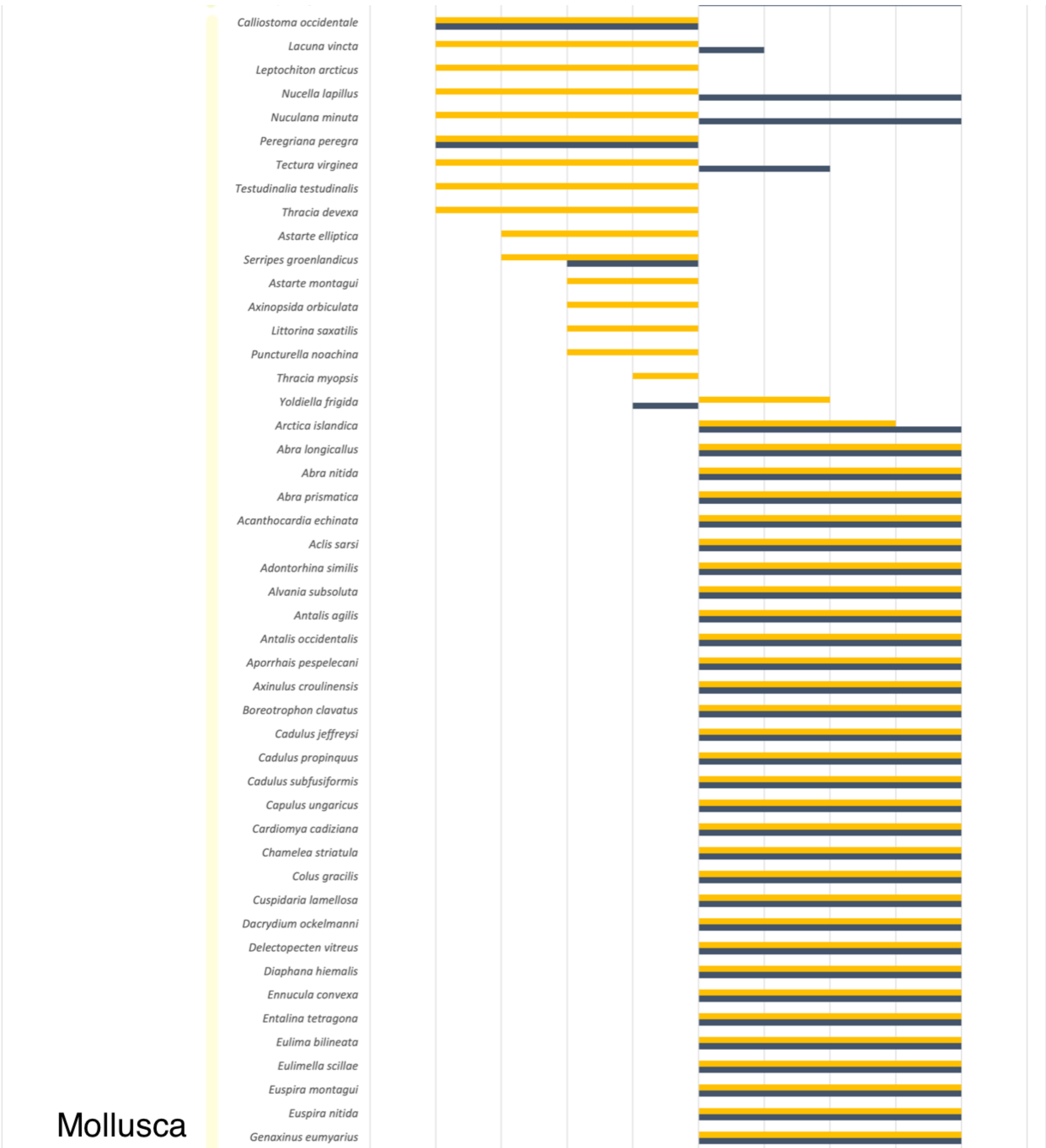

Mollusca
Liocyma fluctuosa
Peregriana peregra
Nuculana minuta
Astarte elliptica
Serripes groenlandicus
Tectura virginea
Thracia myopsis
Astarte montagui
Erginus rubellus
Littorina saxatilis
Testudinalia testudinalis
Yoldiella frigida
Abra nitida
Adontorhina similis
Antalis agilis
Antalis occidentalis
Aporrhais pespelecani
Bathypolypus arcticus
Boreacola maltzani
Chamelea striatula
Colus gracilis
Cuspidaria lamellosa
Dacrydium ockelmanni
Delectopecten vitreus
Entalina tetragona
Eulima bilineata
Euspira montagui
Frigidoalvania janmayeni
Genaxinus eumyarius
Haliella stenostoma
Hanleya hanleyi
Hermania scabra
Iothia fulva
Kellia suborbicularis
Kelliella miliaris
Kurtiella bidentata
Lacuna crassior
Leptaxinus minutus
Leptochiton alveolus
Limatula gwyni
Limea crassa
Limopsis aurita
Limopsis cristata
Limopsis minuta
Littorina littorea
Lucinoma borealis
Margaritifera margaritifera
Mendicula pygmaea
Modiolula phaseolina
Mohnia parva
Montacuta substriata
Nucula tumidula
Odostomia unidentata
Oenopota cinerea
Oenopota pyramidalis
Onoba semicostata
Parvicardium pinnulatum
Pecten maximus
Pododesmus patelliformis
Poromya granulata
Pusillina inconspicua
Rissoa parva
Scaphander lignarius
Skeneopsis planorbis
Steromphala cineraria
Tachyrhynchus erosus
Taranis moerchii
Tellimya ferruginosa
Timoclea ovata

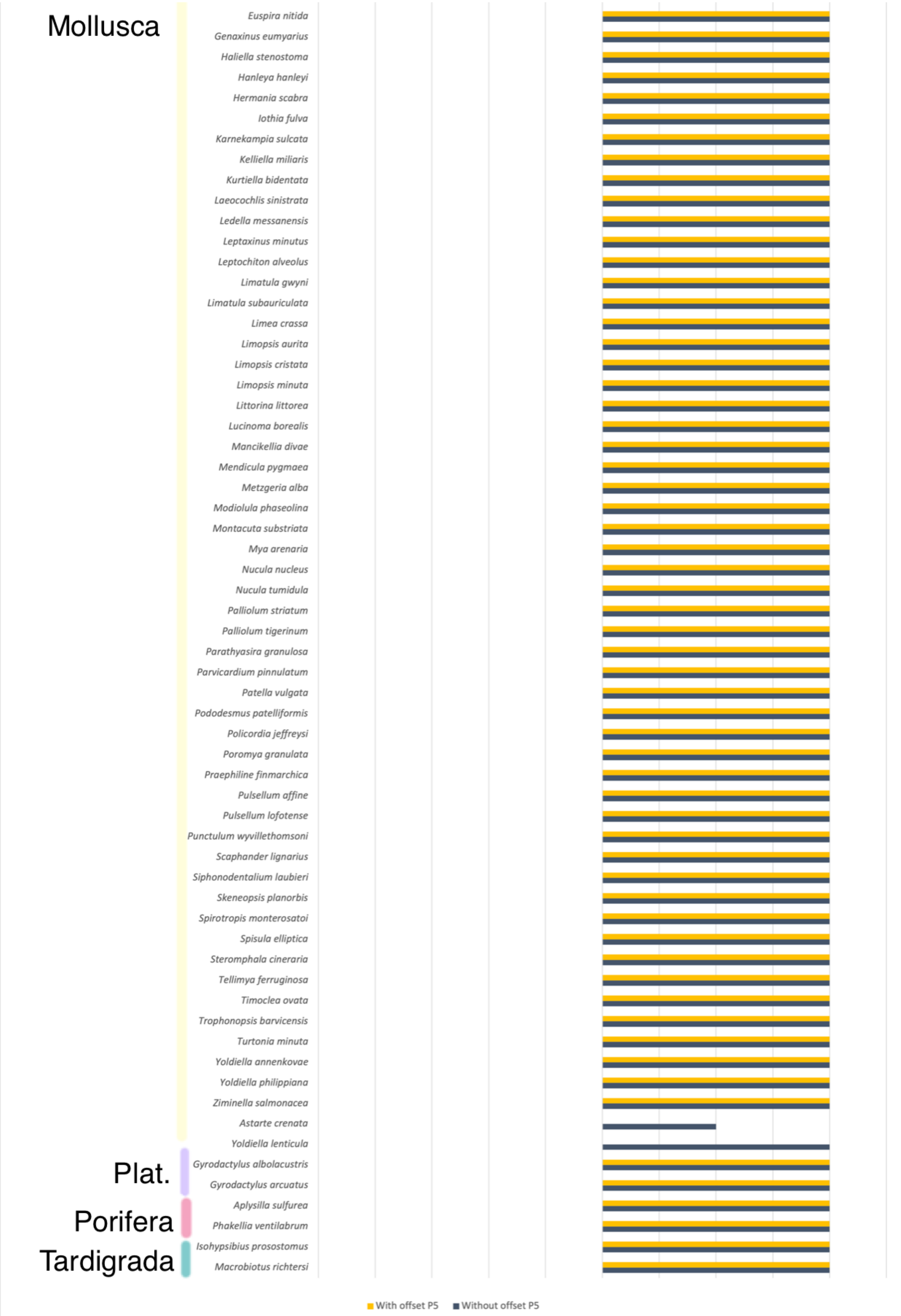

Mollusca
Nematoda
Platyhelminthes
Porifera
Timoclea ovata
Trophonopsis barvicensis
Turrisipho voeringi
Turtonia minuta
Varicorbula gibba
Yoldiella philippiana
Arctica islandica
Astarte crenata
Lacuna vincta
Yoldiella lenticula
Paracuaria adunca
Gyrodactylus arcuatus
Cladorhiza gelida
Polymastia mamillaris
Thenea abyssorum
With offset P4
Without offset P4

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
Calliostoma occidentale
Lacuna vincta
Leptochiton arcticus
Nucella lapillus
Nuculana minuta
Peregriana peregra
Tectura virginea
Testudinalia testudinalis
Thracia devexa
Astarte elliptica
Serripes groenlandicus
Astarte montagui
Axinopsida orbiculata
Littorina saxatilis
Puncturella noachina
Thracia myopsis
Yoldiella frigida
Arctica islandica
Abra longicallus
Abra nitida
Abra prismatica
Acanthocardia echinata
Aclis sarsi
Adontorhina similis
Alvania subsoluta
Antalis agilis
Antalis occidentalis
Aporrhais pespelecani
Axinulus croulinensis
Boreotrophon clavatus
Cadulus jeffreysi
Cadulus propinquus
Cadulus subfusiformis
Capulus ungaricus
Cardiomya cadiziana
Chamelea striatula
Colus gracilis
Cuspidaria lamellosa
Dacrydium ockelmanni
Delectopecten vitreus
Diaphana hiemalis
Ennucula convexa
Entalina tetragona
Eulima bilineata
Eulimella scillae
Euspira montagui
Euspira nitida
Genaxinus eumyarius



Mollusca
Euspira nitida
Genaxinus eumyarius
Haliella stenostoma
Hanleya hanleyi
Hermania scabra
Iothia fulva
Karnekampia 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
Mancikellia divae
Mendicula pygmaea
Metzgeria alba
Modiolula phaseolina
Montacuta substriata
Mya arenaria
Nucula nucleus
Nucula tumidula
Palliolum striatum
Palliolum tigerinum
Parathyasira granulosa
Parvicardium pinnulatum
Patella vulgata
Pododesmus patelliformis
Policordia jeffreysi
Poromya granulata
Praephiline 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
Plat.
Gyrodactylus albolacustris
Gyrodactylus arcuatus
Porifera
Aplysilla sulfurea
Phakellia ventilabrum
Tardigrada
Isohypsibius prosostomus
Macrobiotus richtersi
With offset P5
Without offset P5