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PANABIO: A point-referenced pan-Arctic data collection of benthic biotas

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Abstract. Profound environmental changes, such as drastic sea-ice decline, leave large-scale ecological footprints on the distribution and composition of marine biotas in the Arctic. Currently, the impact of such stressors is not sufficiently understood due to the lack of pan-Arctic data that allow for estimating ecological baselines, as well as modelling current and forecast potential changes in benthic biodiversity and ecosystem functioning. Here, we introduce a PAN-Arctic data collection of benthic BIOtas (PANABIO), and discuss its timeliness, potential, and details of its further development. The data collection contains records of benthic fauna at genus-level or species-level identified in field samples obtained by means of grabs, towed gear, or seabed imaging. Currently, it includes records of 2,968 species or genera, ranging from presence to counts, densities or biomass, grouped per sample. The data represent the pan-Arctic realm, covering all major marine areas, i.e., the central Arctic Ocean, Chukchi Sea, East Siberian Sea, Laptev Sea, Kara Sea, Barents Sea (incl. White Sea), Svalbard waters, Greenland Sea, Norwegian Sea, Canadian Archipelago, Beaufort Sea, and Bering Sea. All data are point-referenced sampling locations. Currently, 124,040 records from 10,645 samples taken at 10,631 stations between 1800 and 2014 are included, but these numbers will increase with more data becoming available. The data collection is available in a PostgreSQL-based data warehouse that can be accessed and queried through an open-access frontend web service at https://critterbase.awi.de/panabio. A snap shot of the current data collection (of 26 June 2023) is also available from the data publisher PANGAEA.

1 Introduction

Climate change progresses faster and stronger in the Arctic than elsewhere (Meredith et al., 2019; Constable et al., 2022). Therefore, Arctic marine organisms and ecosystems are particularly affected and potentially threatened at large scales by accelerating environmental change, such as ocean warming and acidification, sea-ice decline and increased riverine input (Kedra et al., 2015), albeit with distinct regional differences. Moreover, expanding human activities, such as exploration and exploitation of natural resources, ship traffic and tourism, add further pressures. Accordingly, there is an urgent need for a thorough and rapid assessment of how environmental changes may alter ecosystems and their functioning in polar latitudes

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(Degen et al., 2018). However, research on footprints and implications of climate change and direct anthropogenic impacts, such as range shifts, changes in abundance, declines in growth and condition, as well as community and regime shifts, has been hampered by the problems to access sound data, which is unevenly distributed among regions and taxonomic groups (Wassmann et al., 2011).

Recent research emphasized the critical importance of the direct and indirect ecological effects of sea-ice decline, which is one of the most striking and far-reaching footprints of climate change in polar regions (Macias-Fauria & Post, 2018). Sea-ice is a dominant ecological driver in Arctic seas, as it not only represents an own, specifically polar marine habitat, but also controls the light, stratification and, hence, productivity regime of the underlying water column (Bluhm & Gradinger, 2008). Both pelagic and benthic secondary production depend directly on sea-ice and pelagic primary production. Ultimately, due to the importance of the cryo-pelagic-benthic coupling in polar seas, the loss of sea-ice will very likely have profound consequences for the diversity, structure, and functioning of benthic fauna across pan-Arctic seascapes (Piepenburg, 2005; Hinzman et al., 2011; Macias-Fauria & Post, 2018; Wassmann et al., 2011).

However, the challenge of quantifying, understanding, modelling and forecasting the impact of climate-change and anthropogenic pressures on Arctic benthic species and assemblages has rarely been addressed (e.g., Renaud et al., 2019; Pantiukhin et al., 2021). Indeed, it is commonly acknowledged that currently neither the direction nor mode of ongoing or future ecological regime shifts are sufficiently investigated and understood to soundly predict forthcoming changes in Arctic marine ecosystem functions (Wassmann et al., 2011; Post et al., 2013; Meredith et al., 2019; Constable et al., 2022). This gap can be attributed to the difficulty to obtain solid data from the Arctic due to, amongst others, its remoteness and hostile environmental conditions, the tremendous costs of sea-going polar research, as well as a lack of synergistic research spanning multiple Arctic ecoregions.

Consequently, the urgently needed integrative approach can only be achieved through an upscaling from local to large scales, but this would require a comprehensive data source representative of the whole Arctic. Here, we present PANABIO, a PAN-Arctic data collection of benthic BIOtas (critterbase.awi.de/panabio) within the CRITTERBASE data warehouse (Teschke et al., 2022). It provides standardized open access to point-referenced quantitative ecological data by integrating data from various sources and of various formats through a generic data-ingest interface and offering versatile exploration tools for data filtering and mapping provided by the overarching CRITTERBASE system.

2 Material and methods

2.1 Definition of study area

We used the common definition of Arctic seas proposed by the Arctic Monitoring and Assessment Programme (AMAP; www.amap.no) to identify our pan-Arctic study area (Figure 1; Table 1). In the global CRITTERBASE data warehouse, the PANABIO data collection can be filtered by the statistical areas used by the Food and Agriculture Organization of the United Nations (FAO).

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2.2 Data sources

We compiled point-referenced information about benthic taxa from 28 data sources, a total of 17 of which have previously been compiled during the Arctic Ocean Diversity (ArcOD) project (see Piepenburg et al., 2011) and/or are published in the PANGAEA data repository (www.pangaea.de) and the Arctic OBIS node (https://obis.org/node/da50007b-7871-46cf-8530-441b5836d2c1). The provenance of each data source is indicated, including contact person and DOI of a representative peer-reviewed article and/or data publication (if available). Note that this represents an initial stock, and more data will be added as the project progresses, resulting in more data sources, more samples per year, a wider temporal range with a higher spatial sampling density, and extended taxonomic coverage.

2.3 Data compilation

Following the workflow suggested by Piepenburg et al. (2011), we first harmonised and validated the nomenclature by consistently using the valid taxon name according to the World Registry of Marine Species (WoRMS; www.marinespecies.org). This prevents confounding of cross-data comparisons and inflation of diversity estimates due to the use of synonyms or unaccepted species names. All records that refer to a taxonomic rank higher than genus were excluded. Therefore, to the best of our knowledge, each record in the validated data collection represents a single taxonomic unit (either species or genus) and not a mix of various species and genera.

Data records provide information about the occurrence (presence) or, if available, abundance (density) and/or biomass (wet mass or ash-free dry mass) of each taxon encountered and identified in a sample taken at a specific place at a specific time. Metadata informs about geographic location, region, water depth (m) and date of sampling , as well as sampling gear used (such as towed trawls, grabs, corers, or seafloor imaging). The latter determines which part of the benthic community is generally represented in the samples, e.g., trawl catches contain mainly megabenthos, grab samples macrobenthos, and seafloor images epibenthos. Metadata also provide information about the taxonomic coverage of the data set, to indicate it comprises only a certain taxonomic subset of the entire benthic fauna (e.g., "polychaetes" because only this group has been analysed in the samples on species or genus level). Furthermore, the full taxonomic tree is given for each taxon, to allow for summarising and scaling information from species to kingdom level. For more detailed information about the data model and data quality control, see Teschke et al. (2022) and critterbase.awi.de/#qc.

3 Data availability

Currently, PANABIO contains 124,040 records from 10,645 samples taken at 10,631 stations (Table 1; Figure 2), and 2,968 taxonomic entities at species or genus level (Table 1), collected between 1800 and 2014. These circumpolar data on Arctic benthic biodiversity, comprising mainly Echinodermata, Arthropoda, Mollusca, and Annelida, are hosted as the Arctic regional component of the PostgreSQL-based global data warehouse CRITTERBASE (Teschke et al., 2022), and can be accessed via a web portal at critterbase.awi.de/panabio. Here, the entire data collection (https://critterbase.awi.de/preview/#map-panabio) or, if required, only excerpts of it can be downloaded as CSV and/or Excel files, to be used for further analysis. Moreover, a snap shot of the current version of the PANABIO data collection (of 26 June 2023) is available from PANGAEA via [temporary link because a PANGAEA doi has not yet been assigned: https://docs.google.com/spreadsheets/d/14LZuBPtxVHIUEwaqU39P19N4cty_0acCrKxhRDT_nFs/edit?usp=sharing] (Piepenburg et al., under review).

4 Discussion

4.1 Timeliness

Open-access data collections on pan-Arctic benthic biotas, such as PANABIO, are needed to explore and forecast potential impacts of climate change on benthic diversity and food-web complexity and its consequences for higher trophic levels, such as marine mammals and seabirds, relying on benthic fauna for food (Macias-Fauria & Post, 2018; Post et al., 2013; Wassmann et al., 2011). Moreover, they are also needed to obtain a scientifically sound baseline of current diversity patterns in Arctic benthic systems, from which further change can be assessed. PANABIO does not aim to replace but rather complement the services offered by common and well-established data repositories, such as, e.g., the Global Biodiversity Information Facility (GBIF; https://www.gbif.org/), the Ocean Biodiversity Information System (OBIS; https://obis.org/) and PANGAEA. There is one crucial difference: While such repositories focus on long-term data storage, and/or on individual datasets, PANABIO provides a "ready-to-use", standardised and quality-checked compilation of many individual data sets. Moreover, it has a distinct focus on Arctic benthos, facilitating instant and low-level access to relevant data for the Arctic benthic research community, as well as providing an attractive tool for cooperation and networking. It is currently used as a tool for managing and exploring the first comprehensive bottom grab-sample survey of the Marine Benthos Expert Network of the Circumpolar Biodiversity Monitoring Program (CBMP) of the Arctic Council working group Conservation of Arctic Flora and Fauna (CAFF) (https://www.caff.is/marine/marine-expert-networks/benthos). Such results are also important for informing decision makers and the general public, who are concerned about the vulnerability of Arctic environments due to emerging and rapidly increasing economic and geopolitical interests.

4.2 Outlook

Arctic marine biotic data are still fragmented into a dazzling array of databases and files, most of which are not public. This situation seriously hampers progress in Arctic marine ecological research, as it prevents us from coupling environmental dynamics to ecological dynamics across large spatial and temporal scales. Currently this problem is tackled from various sides, e.g., WoRMS addresses marine taxonomic inconsistencies at a global scale (WoRMS Editorial Board, 2023), AquaMaps (Kaschner et al., 2016) provides ecological and biological information on marine species, and OBIS (De Pooter, 2017) allows to explore marine species occurrences in relation to environmental conditions. In the context of these ongoing and planned efforts, PANABIO represents a regional data collection of the ecological information system CRITTERBASE with an open-

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access web service that allows on-the-fly exploration, selection and download of geo-referenced and validated circum-Arctic benthic biodiversity data. What is still lacking from the PANABIO data collection and what we currently are investing in is the compilation of data layers from the pan-Arctic region, such as raster information on bottom topography, sea-ice and ocean dynamics, or Chlorophyll *a* distribution patterns. This would support analysis/modelling work in day-to-day operations, as it would not be necessary to pick data layers from the various existing environmental databases before each analysis. In addition, the free availability of the PANABIO data collection via CRITTERBASE and PANGAEA (where static snap shots of the collection will be published at regular time intervals) will be complemented through an interface to the two global biodiversity networks GBIF and OBIS.

Competing interests

The authors declare no competing interests.

Author contributions

All authors contributed to information system design, data collection, curation & analysis, as well as writing and reviewing of the manuscript. CK and DP wrote the first version of the manuscript.

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TABLE 1: Summary of the data contained within the pan-Arctic data collection of benthic biotas (PANABIO): Number of stations, samples, records and taxa by FAO areas (each encompassing various Arctic sea regions). Please note that the number of taxa in the five FAO areas do not sum up because taxa can occur in two or more areas

FAO Areas	Arctic sea regions	# of Stations	# of Samples	# of Records	# of Taxa
#18: Arctic Sea	Central Arctic Ocean Chukchi Sea East Siberian Sea Laptev Sea Kara Sea Beaufort Sea Canadian Archipelago Hudson Bay	3,839	3,853	84,827	1,941
#21: Northwest Atlantic	Baffin Bay Labrador Sea	82	82	4,286	661
#27: Northeast Atlantic	27.1: Barents Sea + White Sea 27.2: Norwegian Sea + Svalbard + Fram Strait 27.5: Iceland 27.14: Greenland Sea	5,048	5,048	30,101	1,691
#61: Northwest Pacific	Western Bering Sea Sea of Okhotsk Sea of Japan	1,478	1,478	3,238	237
#67: Northeast Pacific	Eastern Bering Sea	184	184	1,588	124
	Totals	**10,631**	**10,645**	**124,040**	**2,968**

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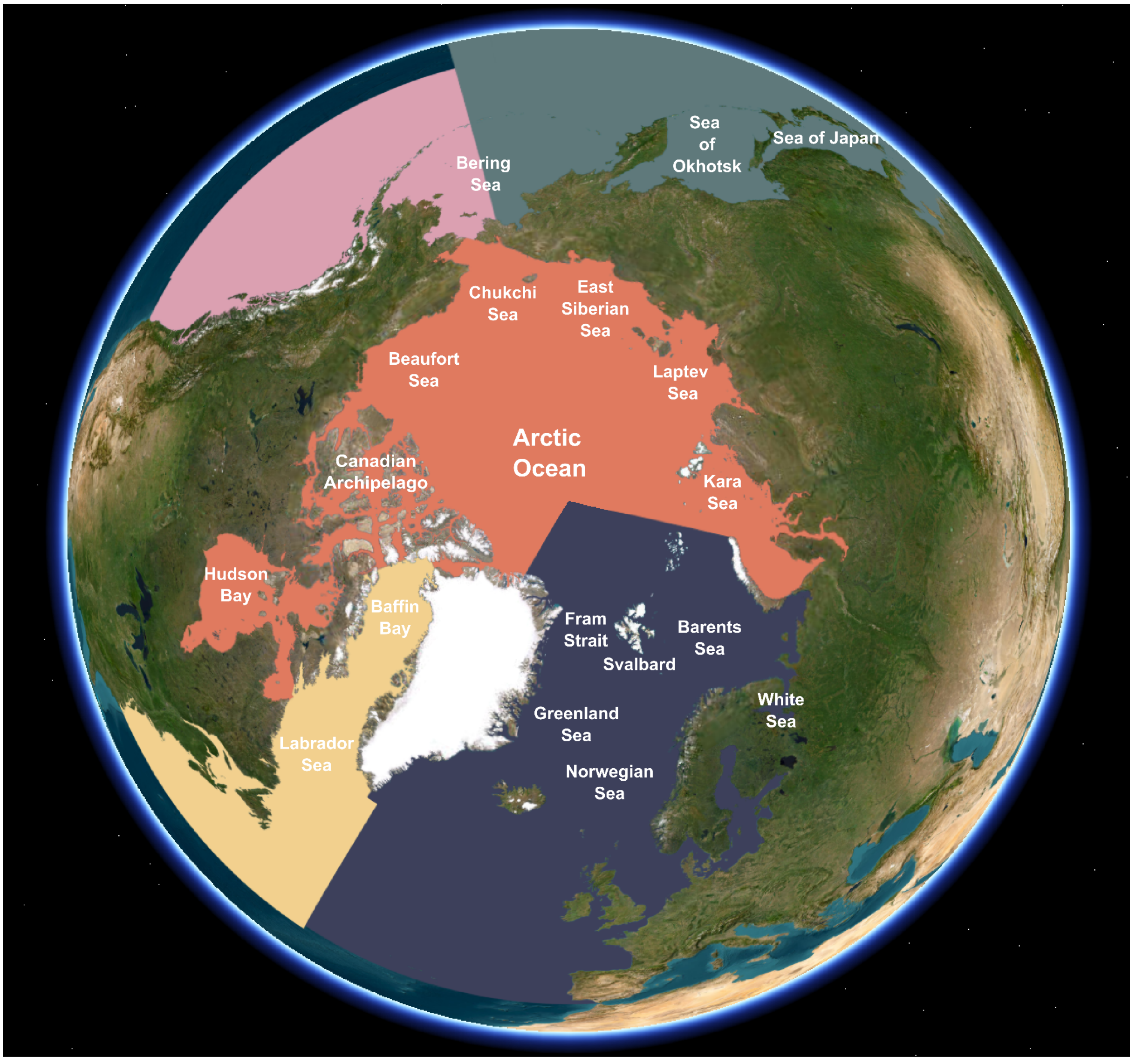

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FIGURE 2: Locations of point-referenced data in the PANABIO data collection, embedded in five Major Fishing Areas of the Food and Agriculture Organization (FAO) (Orange: #18 – Arctic Sea; Yellow: #21 – Northwest Atlantic; Blue: #27 – Northeast Atlantic; Green: #61 – Northwest Pacific; Purple: #67 – Northeast Pacific). The map was created with ArcGIS Earth (Earthstar Geographics esri).