SUMMER

Sustainable management of mesopelagic resources

D1.2 SUMMER background knowledge available in open access

2021-02-28

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	Lead beneficiary: University of Bremen
	Prepared by: Astrid Wittmann,UBREMEN Laura Alonso-Sáez, AZTI Martina Blümel, GEOMAR Mónica Estupiñán, AZTI Jorge Galino Barres, LEITAT Santiago Hernández-León, ULPGC Bruno Iñarra Chastagnol, AZTI Sigrun Jonasdottir, DTU Aqua Stein Kaartvedt, UiO Tor Knutsen, HI Martin Lindegren, DTU Aqua Adrian Martin, NOC Beatriz Benguria, UIO Dag Aksnes, UIB Tom Anderson, NOC Javier Aristegui, ULPGC Mokrane Belharet, IRD Andrew Brierley, USTAN Chris Lindemann, UIB Sari Giering, NOC Nauzet Hernandez, ULPGC Olivier Maury, IRD M. Pilar Olivar, CSIC Christophe Pampoulie, MFRI Roland Proud, USTAN Mónica Silva, IMAR Jérôme Spitz, ULR
	Approved by: Astrid Wittmann

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Abstract
The SUMMER project will explore recent findings that suggest that the global ocean's mesopelagic zone contains 90 % of the planet's fish biomass. Even if this is correct by only a fraction of this value, the exploitation potential in fishmeal production, nutraceuticals and pharmaceuticals is enormous. However, as the role of mesopelagic fish in pelagic ecosystems is not well understood, it is necessary to first establish methods to accurately estimate their biomass, taxonomic/functional diversity, contribution to the global carbon cycle and potential as a sustainable fishery. Using state-of-the-art tools (e.g. eDNA, acoustics and gut analysis), SUMMER will also investigate environmental repercussions of such exploitation, and quantify the impact of commercial extraction on pelagic ecosystems. This deliverable reports on the outcomes of Task 1.2: "Assemble relevant research outputs from research". It addresses the second objective of Work Package 1, which is to compile background knowledge suitable to contributing to the scientific objectives of the SUMMER project. In total, 160 literature and 200 data references were identified, covering topics on mesopelagic resources with a focus on taxa specific biomass and community composition. The references and links are provided as Excel table and reference database in .ris format in open access. Ca. 1 TB of historical echosounder, abundance and biomass data were published in open access under this task via the databases PANGAEA and NMDC.

Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission services)	
CI	Classified information as referred to in Commission Decision 2001/844/EC)	

Deliverable type		
R	Document, report	X
DEM	Demonstrator, pilot, prototype	
DEC	Web sites, patent fillings, videos, etc.	
OTHER	Software, technical diagram, etc.	

Authorship information	
Editor	Astrid Wittmann, UBREMEN, PANGAEA Germany https://orcid.org/0000-0002-4839-5633
Contributing partners	Laura Alonso-Sáez, AZTI, Spain
	Bruno Iñarra Chastagnol, AZTI, Spain
	Mónica Estupiñán, AZTI, Spain
	Roland Proud, USTAN, UK
	Mónica Silva, IMAR, Portugal
	Martina Blümel, GEOMAR, Germany

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	Stein Kaartvedt, UiO, Norway
	Jérôme Spitz, ULR, France
	Tor Knutsen, HI, Norway
	Jorge Galino Barres, LEITAT, Spain
	Christophe Pampoulie, MFRI, Iceland
	Sigrun Jonasdottir, DTU Aqua, Denmark
	Martin Lindegren, DTU Aqua, Denmark
	Adrian Martin, NOC, UK
	M. Pilar Olivar, CSIC, Spain
	Santiago Hernández-León, ULPGC, Spain
	Beatriz Benguria, UIO, Norway
	Dag Aksnes, UIB, Norway
	Tom Anderson, NOC, Spain
	Javier Aristegui, ULPGC, Spain
	Mokrane Belharet, IRD, France
	Andrew Brierley, USTAN, UK
	Chris Lindemann, UIB, Norway
	Sari Giering, NOC, UK
	Nauzet Hernandez, ULPGC, Spain
	Olivier Maury, IRD, France

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SUMMER H2020 consortium

SUMMER H2020 (817806) is a Research and Innovation Action within Horizon 2020, the European Union's framework programme for research and innovation, H2020-BG-2018-2, Topic *Sustainable harvesting of marine biological resources,* LC-BG-03-2018, and is carried out by 22 partner organizations (Table 1).

Table 1: Information about the consortium members

AZTI MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE	AZTI-BRTA (AZTI) 48395 Sukarrieta SPAIN www.azti.es	Xabier Irigoien xirigoien@azti.es Raul Prellezo rprellezo@azti.es +34 667 174 368
Universität Bremen	Universität Bremen (UBREMEN) Bibliothekstraße 1 28359, Bremen GERMANY www.uni-bremen.de	Astrid Wittmann awittmann@marum.de +49 421 218 65629
University of St Andrews	The University of St Andrews (USTAN) North street 66 College Gate KY16 9AJ, St Andrews UNITED KINGDOM www.st-andrews.ac.uk/	Andrew Brierley asb4@st-andrews.ac.uk +44 133 446 3458
imar	Instituto Do Mar (IMAR) Rua Prof Dr Frederico Machado 4 Horta, 9901-862 PORTUGAL	Mónica Silva monica.silva.imar@gmail.com +351 292200400
National Oceanography Centre	National Oceanography Centre European Way Southampton SO14 3ZH UNITED KINGDOM https://www.noc.ac.uk/	Adrian Martin adrian.martin@noc.ac.uk +44 238 059 342
GEOMAR Helmholtz Centre for Ocean Research Kiel	Helmholtz Centre for Ocean Research Kiel (GEOMAR) Am Kiel-Kanal 44 24106 Kiel GERMANY www.geomar.de	Deniz Tasdemir dtasdemir@geomar.de +494316004430
UiO : University of Oslo	University of Oslo (UIO) Problemveien 5-7	Stein Kaartvedt stein.kaartvedt@ibv.uio.no

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	0313 Oslo NORWAY www.uio.no	+47 22854739
	University of Bergen (UIB) Museplassen 1 5020 Bergen NORWAY www.uib.no	Dag Lorent Aksnes dag.aksnes@uib.no +47 55584478
	Consejo Superior de Investigaciones Científicas (CSIC) Calle de Serrano 117 28006 Madrid SPAIN www.csic.es/	M. Pilar Olivar polivar@icm.csic.es +34932309556
	Université de La Rochelle (ULR) Avenue Albert-Einstein 23 17031 La Rochelle FRANCE www.univ-lr.fr	Jérôme Spitz jerome.spitz@univ-lr.fr +33 546449910
	Institut Français pour l'Exploitation de la Mer (IFREMER) 155 rue Jean Jacques Rousseau 92138, ISSY-LES-MOULINEAUX FRANCE wwz.ifremer.fr/	Verena Trenkel verena.trenkel@ifremer.fr +33 240374157
	University of Strathclyde (USTRATH) Richmond St 16 G1 1XQ, Glasgow UNITED KINGDOM https://www.strath.ac.uk/	Michael Heath m.heath@strath.ac.uk +44 1415483591
	Universidad De Las Palmas De Gran Canaria (ULPGC) Juan de Quesada 30 35001, Las Palmas De Gran Canaria SPAIN www.ulpgc.es/	Santiago Hernández-León shernadezleon@ulpgc.es +34928452907
	Institut de Recherche pour le Développement (IRD) Boulevard De Dunkerque, 44 CS90009 13572, Marseille FRANCE www.ird.fr/	Olivier Aumont olivier.aumont@ird.fr +33 (0)1 44 27 46 27

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	DTU Aqua (DTU) Anker Engelundsvej 1 Bygning 101 A 2800, KGS Lyngby DENMARK www.dtu.dk	Martin Lindegren mli@aqua.dtu.dk +4535883492
	Havforskningsinstituttet (HI) Nordnesgaten 50 5817 Bergen NORWAY www.imr.no/	Tor Knutsen tor.knutsen@hi.no +4755238500
	SINTEF Ocean (SO) Otto Nielsens veg 10 7052 Trondheim NORWAY www.sintef.no/ocean	Rachel Tiller Rachel.Tiller@sintef.no +4792200886
	Middle East Technical University (METU) Dumlupinar Bulvari 1, 06800 Ankara TURKEY www.metu.edu.tr/	Baris Salihoglu baris@ims.metu.edu.tr +903245212150
	Acondicionamiento Tarrasense Associacion (LEITAT) Carrer de la Innovació 2, 08225 Terrassa SPAIN www.leitat.org	Dirk Saseta international@leitat.org +34937882300
	Marine and Freshwater Research Institute of Iceland (MFRI) Skúlagata 4 101 Reykjavík ICELAND www.hafogvatn.is/en	Christophe Sebastien Pampoulie chrisp@hafogvatn.is +3545752038
	BARNA S.A. (BARNA) Ctra De Bermeo S/N 48360 Mundaka SPAIN www.barna.es	Ibon Jaureguizar ibon@barna.es +34946187265
	King Abdullah University of Science and Technology (KAUST) Administration Building 16 Level 4 Roo, 23955 6900, Thuwal SAUDI ARABIA www.kaust.edu.sa/en	Carlos Duarte carlos.duarte@kaust.edu.sa

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Executive summary

Deliverable 1.2 reports on the results of Task 1.2 and their relevance to other Work Packages (WPs). It describes the objectives, structure and contents of the resource collation relevant to SUMMER.

The objective of Task 1.2 is to identify and compile references to existent resources, i.e. literature, data, maps and model outputs addressing research on the mesopelagic ecosystem and its services. Furthermore, this task aimed to make previously unpublished historical data freely available to science and industry stakeholders according to the FAIR principles (Findable, Accessible, Interoperable, Reusable).

Data and literature records, which include keywords, persistent identifiers and linked publications, were appended to an Excel worksheet. To facilitate proper citation of the resources, i.e. using a reference management system, a reference database in .ris format was generated. Persistent identifiers/links were included where possible to enable long-term findability of the resources and re-use of this collation. The deliverable and the collation of resources are provided in open access.

In addition to WP1 partners, WPs 2 – 5 also contributed to this task. Searches for literature and data on the mesopelagic zone (200 – 1000 m depth) covered a wide array of topics, including: i.) biomass estimates from multi-frequency and broadband echosounders; ii.) catch and bycatch data; iii.) diet and trophic level data; iv.) daily feeding rates for key mesopelagic species; v.) distribution, behavior, and vertical migrations of megafauna; vi.) predator abundance and biomass; vii.) biodiversity and eDNA resources; viii.) migration patterns and ranges of biomass, and high value products. Restricted resources were also included in the collation where a metadata record existed, and data that are not yet publicly available (but relevant to SUMMER) were identified.

The resource collation comprises 160 literature references and 200 data references from 13 repositories. Literature sources mainly comprised published scientific articles in peer-reviewed journals. Data references typically referred to first-hand data, ranging from individual datasets (KBs – MBs) to entire data collections (>100 TB). In total, 44% of the literature was accompanied by (or made use of) open access data and 65% of the dataset records included references to related literature. Archiving and publishing of historical data relevant to SUMMER is still ongoing. So far, ca. 1 TB of echosounder and biological data were published via the databases PANGAEA – Data Publisher for Earth and Environmental Science and the Norwegian Marine Data Centre (NMDC). These data represent a highly valuable resource for further work within the SUMMER project.

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1 SUMMER H2020 motivation and background

Recent studies estimate that the biomass of mesopelagic fish is 10,000 million tonnes, which has raised interest in the harvest and exploitation of fish in the mesopelagic zone as a new resource for fishmeal, pharmaceuticals and nutraceuticals. The objective of SUMMER H2020 is to establish a protocol to estimate mesopelagic fish biomass, quantify the ecosystem services provided by the mesopelagic community (food for aquaculture, for humans, for other wild fish, climate regulation and potential for bioactive compounds) and develop a decision-making support tool to quantitatively balance the trade-offs between the different services for any given exploitation scenario (Figure 1).

SUMMER will develop methods for accurate estimation of mesopelagic diversity and biomass. This will focus on determining the best combination of methods (including submersible broadband acoustics), environmental DNA (eDNA) and scientific trawls. Furthermore, SUMMER will evaluate the role of mesopelagic species in the vertically integrated food web, its "services" as food for commercial fish species (e.g. tuna), deep sea species and emblematic species (e.g. cetaceans) and model the effects of different fishing scenarios on trophic stability. SUMMER also includes a climate perspective as it will determine the contribution of mesopelagic organisms to sequestration of atmospheric carbon dioxide via active vertical migration (the biological carbon pump). This will be done by estimating the carbon sequestration due to active migration relative to the gravitational flux and by modelling the effects of different fishing scenarios.

In terms of exploitation, SUMMER will explore the potential use of the mesopelagic by fishmeal and processed human food industries, and mesopelagic organisms as a source of bioactive compounds for pharmaceuticals and nutraceuticals.

SUMMER will develop a decision support tool to evaluate the trade-offs between different ecosystem services. It will provide a holistic assessment of the services provided by the mesopelagic ecosystem and seeks to establish trade-offs and tipping points between different services under different fish harvesting scenarios.

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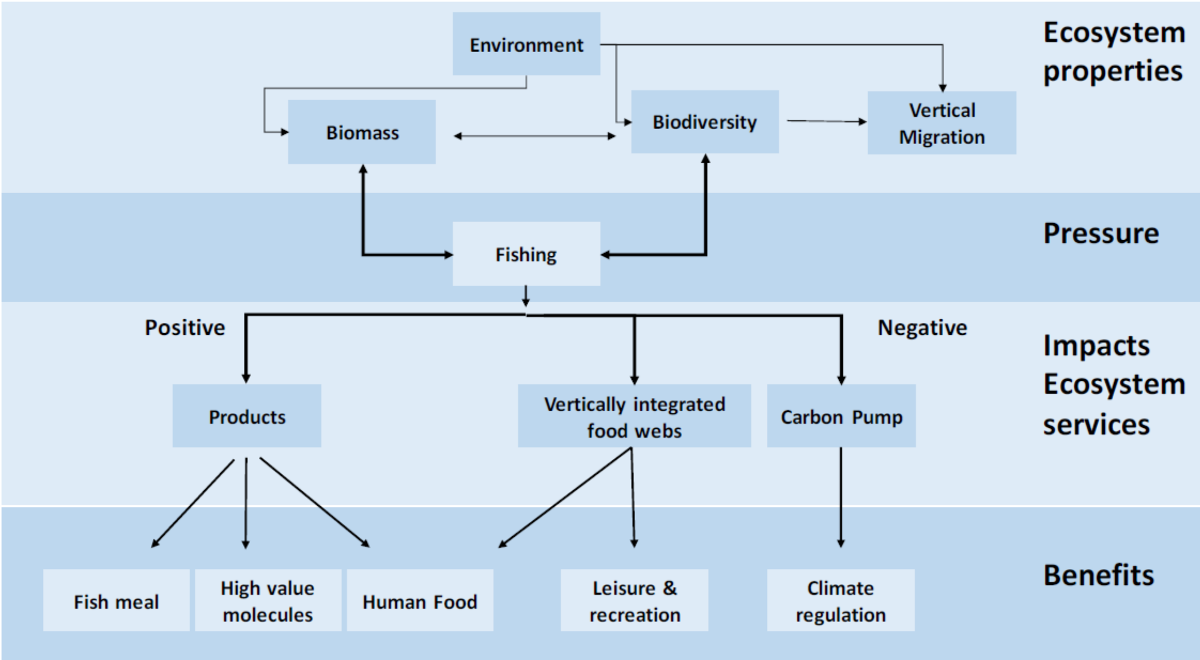

Figure 1: Schematic representation of the ecosystem properties, pressures, ecosystem services and benefits considered in SUMMER.

1.1 Role of deliverable

The goal of WP1 is to foster the Findability, Accessibility, Interoperability and Reusability (FAIRness) of historical resources relevant to SUMMER as well as newly generated data and journal publications by using open science platforms. This deliverable summarizes the results of Task 1.2: "Assemble relevant research outputs from research". Task 1.2 and D1.2 address the second specific objective, which is to assemble background knowledge relevant to the scientific objectives of SUMMER. Task 1.2 identifies and compiles references and provides - where possible - persistent links to literature and datasets relevant to SUMMER. Under this task, ca. 1 TB of historical data were made available in open access via the databases PANGAEA – Data Publisher for Earth and Environmental Science and the Norwegian Marine Data Centre (NMDC).

As this task contributes to tasks in WP2-5, this deliverable is structured by the resources relevant to these WPs. Specifically, these are Task 2.1: "Analysis of existing catch and bycatch data"; Task 3.1: "Food-web data"; Task 3.2: "Food-web interactions"; Task 4.1: "Flux quantification"; Task 4.2: "Influence of mesopelagic organisms on BCP fluxes", and Task 5.3: "Mining metagenomes of culture-independent mesopelagic microbiota for industrial applications". All of these tasks use historical resources collated by WP1 to achieve their objectives. Furthermore, Task 1.2 and D1.2 provide a basis for Task 1.3, which will produce a synthesis of SUMMER research outputs in an open access data journal.

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1.2 Relationship with other deliverables

D1.2 is related to deliverables D2.1, D3.1, D3.2, D4.1, D5.4 and D5.5 (Table 1).

Table 1: Deliverables that relate to D1.2.

Deliverable no.	Deliverable name	Month due	Partner responsible
D2.1	Mesopelagic ecosystem taxonomic and functional biodiversity: Fish species composition and relative abundance from existing data	M18	SO
D3.1	Database of existing diet/trophic level data of key mesopelagic species and predators and of nutritional quality of mesopelagic organisms	M18	IMAR
D3.2	Database of new and existing diet/trophic level data of key mesopelagic species and predators and of nutritional quality of mesopelagic organisms	M36	CSIC
D4.1	Preliminary report on model tools for quantifying role of mesopelagic fish in influencing the BCP	M18	UiB
D5.4	Report on the potential of bacterial metagenomes for omega-3 FA production	M36	AZTI
D5.5	Report on the potential of bacterial metagenomes for enzyme, secondary metabolites and omega-3 FA production for applications	M48	AZTI

1.3 Contributors to this deliverable

The following partners have contributed to this deliverable:

- UBREMEN
- AZTI
- CSIC
- DTU Aqua
- GEOMAR
- HI (IMR)
- IMAR
- IRD
- LEITAT
- MFRI
- NOC

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- UIB
- UiO
- ULPGC
- ULR
- USTAN

1.4 Acronyms and abbreviations

AODN/IMOS	Australian Ocean Data Network/Integrated Marine Observing System
BCP	Biological carbon pump
BODC	British Oceanographic Data Centre
DHA	Docosahexaenoic acid
DOC	Dissolved organic carbon
EMODnet	European Marine Observation and Data Network
ENA	European Nucleotide Archive
EPA	Eicosapentaenoic acid
ETA	Eicosatetraenoic acid
FA	Fatty acid
FAIR	Findable, Accessible, Interoperable, Reusable
LADCP	Lowered acoustic Doppler current profiler
NCEI	NOAA's National Center for Environmental Information
OBIS	Ocean Biodiversity Information System
PKS	Polyketide synthase
PUFA	Polyunsaturated fatty acid
SEANOE	SEA scieNtific Open data Edition
NCBI	National Center for Biotechnology Information
NMDC	Norwegian Marine Data Centre

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2 The collation of resources

The purposes of Task 1.2 are to provide the links to knowledge on mesopelagic resources and to promote publishing of historical data that will be used in the other Work Packages (mainly WPs 2, 3, 4 and 5). Furthermore, it provides an overview of available resources and is a first step towards Task 1.3, in which data will be synthesized and harmonized.

The collation of resources focuses on measures of taxa-specific biomass and community composition. In particular, the topics covered are:

- Biomass estimates from multi-frequency and broadband echosounder
- Catch and bycatch data
- Diet/trophic level data
- Daily feeding rates for key mesopelagic species
- Distribution, behavior and vertical migrations of megafauna
- Predator abundance/biomass
- Biodiversity and eDNA resources
- Migration patterns and ranges of biomass
- High value products

All partners were asked to contribute to the collation by sharing links to resources. The repositories Australian Ocean Data Network/Integrated Marine Observing System (AODN/IMOS), British Oceanographic Data Centre (BODC) and PANGAEA (see Table 2 for web addresses) were explored for data using keywords including "mesopelagic", devices used for data and sample collection (e.g. "echosounder", "multinet", "midwater trawl"), organism groups (e.g. "fish", "zooplankton") and parameters of interest (e.g. "abundance", "diversity", "biomass"), and filtered by water depth (> 200 m). To retrieve unpublished data, researchers and data centres were contacted directly. Literature was identified by running searches on Google Scholar and ResearchGate. Literature related to PANGAEA datasets were also included.

The collation consists of 160 literature references and 200 data references from 13 databases (Table 2). Most literature references are articles from peer-reviewed journals of the discipline. Data citations in most cases refer to original data, ranging from individual datasets (KBs – MBs) to entire data collections (>100 TB). In this deliverable, they are presented in the categories environmental data, which includes data from biological samples as well as physical oceanography and echosounder data, and genetic sequence data. In total, 44% of the literature is accompanied by (or made use of) open access data and 65% of the dataset records include references to related literature.

The complete collation is provided as an Excel sheet containing keywords, the references and where available a persistent link (DOI, accession number) to the resource. Furthermore, a machine readable .ris file was generated, which allows e.g. import into a reference management system. The files are published in open access along with this deliverable. Historical and newly generated data archived at PANGAEA by SUMMER partners are quickly found here: https://pangaea.de/?f.project[]=SUMMER.

The reference list of this deliverable only contains the references cited in the following sections, which briefly summarize and highlight the most relevant resources for the respective Work Packages.

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Table 2: World Wide Web addresses to databases and portals mentioned in this deliverable and used for Task 1.2.

Database / Portal	Web address
AODN/IMOS	https://portal.aodn.org.au/
BODC	https://www.bodc.ac.uk/
Copernicus	https://marine.copernicus.eu/
EMODnet	https://emodnet.eu/en
ENA	https://www.ebi.ac.uk/ena/browser/home
FishBase	https://www.fishbase.in/home.htm
Google Scholar	https://scholar.google.com/
JGI Genome	https://genome.jgi.doe.gov/portal/
MOVEBANK	https://www.movebank.org/cms/movebank-main
NCBI GenBank	https://www.ncbi.nlm.nih.gov/genbank/
NMDC	http://prod1.nmdc.no/UserInterface/#/
NOAA NCEI	https://www.ncei.noaa.gov/
OBIS	https://obis.org/
ResearchGate	https://www.researchgate.net/
SEANOE	https://www.seanoe.org/
UK USTAN	https://risweb.st-andrews.ac.uk/portal/en/datasets/search.html
UTM-CSIC	http://data.utm.csic.es/geonetwork/srv/eng/catalog.search#/search
PANGAEA	https://pangaea.de/
Zenodo	https://zenodo.org/

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2.1 Resources relevant to Work Package 2 - Biodiversity and Biomass

Work Package 2 is focused on delivering baseline biomass estimates and species composition of the mesopelagic community. Spatial analyses will be conducted to reveal global patterns and impact of industrial-scale fishing will be assessed. Estimates will feed into regional-scale ecological models to predict change under various future fishing scenarios. This work relies on a substantial knowledge base and requires analysis of historical data to inform best practice on future SUMMER cruises.

2.1.1 Literature

Compared with other ocean zones, e.g. epipelagic (0 – 200 m), the mesopelagic zone is relatively unknown and understudied (Martin *et al.*, 2020; St. John *et al.*, 2016). SUMMER biomass estimates will build on previous work by developing new methods that combine all available observations to quantify variance and minimise bias and uncertainty. This work requires an extensive back-catalogue of research, which is listed in the sections below. The literature included here is not an exhaustive list but includes most of the work needed to develop new and improved methods of biomass estimation.

Publications in peer-reviewed journals

Previous biomass estimates are predominantly based on acoustic observations (Calleja *et al.*, 2018; Davison *et al.*, 2015; Gjøsæter & Kawaguchi, 1980; Hernández-León *et al.*, 2020b; Irigoien *et al.*, 2014; Kaartvedt *et al.*, 2012; Lam & Pauly, 2005; Proud *et al.*, 2019a; Siegelman-Charbit & Planque, 2016), which require knowledge of the vertical distribution of organisms. Diel vertical migration is likely driven primarily by light (Aksnes *et al.*, 2017; de Busserolles *et al.*, 2013; Kaartvedt, 2008; Langbehn *et al.*, 2019; Norheim *et al.*, 2016; Røstad *et al.*, 2016) but other factors, e.g. oxygen content, food concentration, predator-prey interactions, should also be considered (Drazen & Sutton, 2017; Greely *et al.*, 1999; Hays, 2003; Kaartvedt *et al.*, 2011; Klevjer *et al.*, 2016; Klevjer *et al.*, 2012; Salvanes & Kristoffersen, 2001; Saunders *et al.*, 2017; Saunders *et al.*, 2014; Torgersen, 2001; Van de Putte *et al.*, 2012; Zylinski & Johnsen, 2011). New methods developed during SUMMER will be based primarily on acoustic methods (Davison *et al.*, 2015; Kloser *et al.*, 2016; Lehodey *et al.*, 2015; Proud *et al.*, 2019a; Scoulding *et al.*, 2015; Yasuma *et al.*, 2003). Biomass estimates will then be used to update biogeographies (Béhagle *et al.*, 2016; Collins *et al.*, 2012; Escobar-Flores *et al.*, 2018a, b; Koubbi *et al.*, 2011; Olivar *et al.*, 2012; Olivar *et al.*, 2017; Prihartato *et al.*, 2015; Proud *et al.*, 2017; Proud *et al.*, 2018; Reygondeau *et al.*, 2018; Saunders *et al.*, 2017; Saunders & Tarling, 2018; Sutton *et al.*, 2017) and feed into carbon transfer estimates in WP4 (Davison, 2011; Davison *et al.*, 2013; Schnetzer & Steinberg, 2002) and link to the assessment of industrial fishing impact on the mesopelagic ecosystem (Grimaldo *et al.*, 2020; Standal & Grimaldo, 2020).

Recent work conducted during EURO-BASIN project (see Drinkwater *et al.*, 2020; Klevjer *et al.*, 2020; Melle *et al.*, 2020; Naustvoll *et al.*, 2020; Strand *et al.*, 2020) are particularly interesting comparing four North Atlantic basins with the focus of examining trophic relationships in the four basins, the Labrador, Irminger, Iceland and Norwegian Seas. This is a significant contribution to our understanding of basin specific differences in the mesopelagic and epipelagic domains of the northern Atlantic. From the Norwegian SI_Arctic project another set of publications explore, using acoustics and biological data, the northward distribution of mesopelagic scatterers and changes in biomass apparent from the southern regions of the Norwegian Sea to the doorstep of the Arctic Ocean (Gjøsæter *et al.*, 2017; Knutsen *et al.*, 2017). A north-Norwegian deep fjord investigation of a physonect siphonophore bloom (Knutsen *et al.*, 2018) is also relevant, given that these organisms are probably quite strong scatterers that are also widely distributed in the mesopelagic domain.

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2.1.2 Data

Historical data relevant to SUMMER WP2 includes echosounder observations, trawl and net samples, imagery and eDNA samples that were collected, at least in part, within the mesopelagic zone. Given the vast number of data centres that are now routinely archiving data, this resource amounts to a potentially huge (> 100s TB) data volume. The majority of these data are comprised of raw echosounder observations. No standardised method to process these data is currently universally accepted and hence the only means to ensure that these data are archived is by maintaining their original raw format. Very few image data and no eDNA data were included in this data collection. The use of eDNA in abundance estimation is still a relatively new concept and no data were found that were deemed to be useful for SUMMER. Whilst an extensive image library does exist at MBARI's deep-sea video archive, which includes many images of mesopelagic organisms, the images were not associated with acoustic/trawl observations and were therefore deemed not useful for biomass estimation. Although not listed below, OBIS (https://obis.org/) will be utilised as source of information on species diversity and FishBase (https://www.fishbase.se/home.htm) to extract population parameters. Gridded satellite data products (https://marine.copernicus.eu/) will also be used in this Work Package.

Environmental data

The majority of biological net/trawl data was found on PANGAEA: Stable isotope data of mesozooplankton (Bode & Mompeán, 2020) and zooplankton biomass (Hernández-León *et al.*, 2020a; Hernández-León & Koppelmann, 2020) from the Malaspina Circumnavigation Expedition; fish and invertebrate trawl sampling south and west of Iceland in July 2018/2019 (Ólafsdóttir & Pampoulie, 2020a, b); day and night collections of mesopelagic fish, decapods and cephalopods from scattering layers in western Mediterranean (Abelló *et al.*, 2021; Olivar *et al.*, 2021a); day and night mesopelagic fish catches through the water column in equatorial and tropical Atlantic (Olivar *et al.*, 2021c); larval fish data from stratified plankton samples through the water column in western Mediterranean and equatorial and tropical Atlantic (Olivar *et al.*, 2021b; Olivar *et al.*, 2021d); the list of mesopelagic cephalopod, decapod and fish species present in the North East Atlantic and Mediterranean according to the literature (Abelló *et al.*, 2020); diet composition of the Atlantic Bluefin Tuna (*Thunnus thynnus* L.) collected in 1998-1999 in the Icelandic Basin (Pampoulie & Ólafsdóttir, 2020). Data were also found on the BODC (by request), including zooplankton net/trawl samples from four surveys in the Irminger Sea (2001/2002) (Heath, 2008; Heath *et al.*, 2008), and zooplankton abundance datasets from IMOS (IMOS, 2020a). Furthermore, some image datasets for zooplankton abundance estimations we found on PANGAEA (e.g. Hirche *et al.*, 2015; Kiko *et al.*, 2015).

Selected macroplankton trawl data from cruises of opportunity in the Norwegian Sea by the Institute of Marine Research in Bergen, will be made available via PANGAEA (early 2021). It is also the aim to contribute a selected set of vertically stratified mesozooplankton data from cruises of opportunity in the Norwegian Sea or alternatively add some equivalent historic data if needed. Such data should be relevant as a means of assessing the abundance and biomass of potential prey for some mesopelagic organisms.

Environmental data products can be accessed via EU Copernicus (https://marine.copernicus.eu/). Additional datasets available through PANGAEA include: Lowered acoustic Doppler current profiler (LADCP) data collected during the Malaspina Circumnavigation Expedition (Fraile-Nuez & Hernández-León, 2020), and surface temperature and salinity from the IDEADOS 09 and 10 Cruise (RV Sarmiento de Gamboa), MAFIA Cruise (RV Hespérides) and SUMMER Cruise on RV Sarmiento de Gamboa (Hernández & UTM-CSIC, 2018; Massutí & UTM-CSIC, 2018a, b; Olivar & UTM-CSIC, 2020).

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Both narrowband and broadband echosounder observations are relevant to SUMMER. This collection of echosounder data contains both raw and processed observations. This Work Package will provide recommendations for data processing and future efficient storage of echosounder data.

Historical echosounder data included in this collection: 38 and 120 kHz raw echosounder data collected during the Malaspina Circumnavigation Expedition available on PANGAEA (Martinez *et al.*, 2020); raw 12.5 and 200 kHz echosounder data collected during the Antarctic Circumnavigation Expedition (2016/2017) available on Zenodo (Proud *et al.*, 2019b, 2020); raw multi-frequency data (18/38/70/120/200/333 kHz) routinely collected since 2004 (global coverage) accessed via the NCEI (NCEI, 2011), volume integrated (1 km by 10 m) 38 kHz data routinely collected since 2009 from predominantly fishing vessels in the Indian and Southern Oceans available via IMOS (IMOS, 2020b); echosounder data collected on the RRS James Cook and RRS James Clark Ross since 2006 available on request from the BODC (cruise IDs: JC037, JC049, JC050, JC062, JC066, JR161, JR177, JR179, JR200, JR210, JR211, JR230, JR260, JR262, JR311, AMT24, AMT25, AMT26, AMT28); echosounder data collected on the French PIRATA cruises available via SEANOE (Habasque *et al.*, 2020); summarised deep scattering layer metrics archived at the University of St. Andrews (Le Guen *et al.*, 2017); and continuous acoustic measurements from cabled devices in Masfjorden, Norway available at the NMDC (Kaartvedt *et al.*, 2021). Searching PANGAEA identified potentially relevant echosounder data from German, Norwegian and British research vessels (e.g. (Buenz, 2019; Klages, 2009; Minshull *et al.*, 2019).

The Institute of Marine Research in Bergen has historical data and will collect a substantial amount of new raw acoustic data (narrowband and broadband) from what is defined as cruises of opportunity in the Norwegian Sea. A first subset of selected raw data relevant for SUMMER will be made available to the project via PANGAEA (February 2021).

Sequence data

Genetic sequences of Mediterranean mesopelagic fishes are available at NCBI GenBank and PANGAEA will provide the respective georeferenced sampling data (Bernal *et al.*, 2014; Bernal *et al.*, submitted).

2.1.3 Maps

A shapefile containing spatial polygons for the mesopelagic biogeographical provinces defined in Proud *et al.* (2017) is available through the University of St. Andrews data portal (Proud & Brierley, 2017).

2.2 Resources relevant to Work Package 3 – Food-web Structure and Resilience

2.2.1 Literature

Publications in peer-reviewed journals

A total of 27 publications were identified as potentially relevant for WP3. These include papers on the biodiversity, biomass, distribution, behavior, vertical migrations and feeding ecology of mesopelagic fauna. Data and information from these papers can be used to assess the diet composition of mesopelagic fauna and trophic and non-trophic interactions in the mesopelagic food web (Tasks 3.1 and 3.2). Additionally, these data can inform the development of conceptual food web models in Task 3.3 and provide biogeochemical, physical, biomass and production data necessary for model parameterization.

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2.2.2 Data

Environmental data

Diet/trophic level data - 17 data sources related to diet and energy flow, including stomach content records, composition of stable isotopes and fatty acids, and estimates of trophic position of zooplankton, mesopelagic fish and squids, and predators (fish, marine mammals, elasmobranchs). These data will be used to determine the diet and trophic position of mesopelagic organisms and their predators in Task 3.1, and to quantify trophic and non-trophic links in Task 3.2.

Distribution, behavior and vertical migrations of megafauna – 3 data sources of tracking and sighting data of megafauna will be used to investigate their interactions with mesopelagic prey in Task 3.2.

A number of data sources contain observations potentially useful to parameterize the ensemble of food web models in Task 3.3:

- Measures of physical and biogeochemical variables, such as temperature, salinity and primary production (8 data sources);
- Estimates of trophic efficiency, mortality rates, and length-frequency data that can be used to estimate production rates and fluxes (7 data sources);
- Estimates of fishing effort, catch and bycatch rates by fishery and fishing gear (7 data sources);
- Estimates of biomass of organisms and organic matter (alternatively, estimates of abundance that must then be converted to biomass, 40 data sources);
- Data on functional traits (2 data sources);
- Information on the diversity, distribution and vertical migration of organism that can be used to conceptualize food web models and estimate the fraction of horizontal and vertical habitat occupied (91 data sources)

Sequence data

Genome data – 4 datasets with sequence data of larval stages of mesopelagic fishes (Myctophiformes and Stomiiformes) and size fractionated prokaryotes and protists. Genome reference data will be used in Task 3.1 to support the molecular identification of prey in stomach content data.

2.3 Resources relevant to Work Package 4 – Carbon Storage and Climate Regulation

WP4 examines the importance of the active flux due to daily migrating mesopelagic organisms, relative to the gravitational flux of sinking material and the flux of dissolved organic carbon (DOC). In particular, WP4 aims to measure these three fluxes simultaneously. No published work has previously done this observationally. Hence, much of the material reported here is of more general interest or from previous cruises where a retrospective analysis might be of value.

One historical project which may be re-visited is the UK COMICS project for which a summary can be found in Sanders *et al.* (2016). Additionally, a previous attempt to estimate two of the 3 fluxes (gravitational and active flux from zooplankton and micronekton) simultaneously was carried out by the MAFIA project and published by Hernández-León *et al.* (2019b) as described in 2.3.1.

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2.3.1 Literature

Publications in peer-reviewed journals

The observations of the gravitational flux in the papers reported below (Mouw *et al.*, 2016b, a; Torres-Valdés *et al.*, 2013; Torres Valdés *et al.*, 2014) under 2.3.2 also contain some discussion. These papers/datasets bring together existing observations of the gravitational flux.

The MAFIA project combined data from a tropical and subtropical transect from Brazil to the Canary Islands with other assessments of active flux by zooplankton (Hernández-León *et al.*, 2001; Hernández-León *et al.*, 2019a; Putzeys *et al.*, 2011; Yebra *et al.*, 2005) in the Canary Current System, and other published data. As part of WP4 it is intended to use these publications and data to review the role of these communities in the functioning of the biological carbon pump in order to provide the necessary information to model these processes in the ocean. Data from these studies will be available to the community once published.

An illustration of how the DOC flux may be estimated can be found in Santana-Falcón *et al.* (2017) though a wider discussion of the issues surrounding this flux can be found in the paper given in the next section.

Other literature

A very good up to date discussion of the various pathways of the biological carbon pump associated with particles is presented in Boyd *et al.* (2019). Arístegui *et al.* (2005) contains a discussion of the issues associated with measuring the DOC flux. Giering *et al.* (2014) illustrates the difficulty of making estimates of different fluxes balance.

2.3.2 Data

Environmental data

A comprehensive review of data on the vertical distribution of zooplankton biomass, acoustics using a LADCP, and a review of microplankton and zooplankton respiration, passive and active fluxes, in productive and oligotrophic areas for the global ocean, were published in PANGAEA along with the paper by Hernández-León *et al.* (2020b; Fraile-Nuez & Hernández-León, 2020; Hernández-León, 2020; Hernández-León & Koppelmann, 2020; Hernández-León *et al.*, 2020a). This study was related to the relationship between primary production and zooplankton biomass in the deep ocean at a global scale and the role of this community to sequester carbon.

Mouw *et al.* (2016a) and Torres-Valdés *et al.* (2013) are collections of observations of the gravitational flux for the North Atlantic and globally, respectively. They also contain some information on environmental parameters such as temperature, nutrients etc. Environmental data at any location can be extracted from the World Ocean Atlas (https://www.ncei.noaa.gov/access/world-ocean-database-select/dbsearch.html).

2.3.4 Model outputs

Simultaneous to this report, D4.1 provides a "Preliminary report on model tools for quantifying role of mesopelagic organisms in influencing the biological carbon pump (BCP)". The references found therein are repeated here but for a discussion of them please see that report.

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2.4 Resources relevant to Work Package 5 – High Value Products

Work Package 5 explores the potential use of compounds from mesopelagic micro- and macro-organisms as feed, nutraceutical and pharmaceutical products.

2.4.1 Literature

Publications in peer-reviewed journals

Little scientific evidence exists on bioactive natural products from mesopelagic animals as most studies focused on their distribution or ecology. A first report of anticancer and antimicrobial activity in mesopelagic animals (1 krill species, 6 fish species) from the Mediterranean was recently published (Lauritano *et al.*, 2020). Extraction of the whole animals followed by *in vitro* bioactivity assays revealed anticancer and antibiotic activity for 2 species, the lanternfish *Myctophum punctatum* (liver cancer, methicillin-resistant *Staphylococcus aureus*) and the Mediterranean krill *Meganyctiphanes norvegica* (lung and breast cancer, methicillin-resistant *Staphylococcus aureus*). Chemical fractionation of the extracts revealed eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and eicosatetraenoic acid (ETA) as major compounds. EPA and DHA are known for their anticancer activity and antibacterial activity. Few studies have investigated culturable heterotrophic bacteria from mesopelagic depths (Sanz-Saez *et al.*, 2020; Estupinan *et al*., 2020). Most of them focused on the diversity of free-living bacteria in special environments such as oxygen minimum zones (Mulla *et al.,* 2018; Menezes *et al.,* 2018) or their primary metabolism (Landa *et al.,* 2019) but there is no information on their potential for production of bioactive secondary metabolites except for omega-3-long-chain polyunsaturated fatty acids (PUFAs; Estupinan *et al.,* 2020). Historical data in the research field of bioactive secondary metabolites from culturable microorganisms associated to mesopelagic animals (aim of SUMMER WP5, Task 5.2) are lacking and besides the practical work, which will generate these data, literature research is ongoing throughout the SUMMER project.

Estupiñán *et al.* (2020) report the bioprospection of omega-3 PUFA producers in bacterial isolates obtained from mesopelagic (500 and 1000 m depth) and surface (5 m) seawater samples from the Bay of Biscay. More than 200 isolates were obtained by standard agar-plate culturing and subsequently identified by 16S rDNA sequencing. All isolates were affiliated with three genera: *Vibrio, Alteromonas* or *Pseudoalteromonas*. A genotypic screening was carried out to identify potential omega-3 producers by amplification of a marker gene of the polyketide synthase (PKS) pathway (the *pfaA*-KS domain). Subsequent lipid analysis by gas chromatography/mass spectrometry was carried out to confirm the production of EPA (20:5n-3) and/or DHA (22:6n-3) by the selected candidates (Estupiñán *et al.*, submitted-a; Estupiñán *et al.*, submitted-b). The analysis unveiled that only a selection of isolates affiliated with *Vibrio* sp. were able to produce omega-3 PUFAs, particularly EPA, and intraspecific variation in the levels of EPA synthesis was found in isolates harbouring different *pfaA*-KS genetic variants. Contributing to subtask 5.3.2 of WP5, which aims at identifying novel microbial producers of omega-3 fatty acids in mesopelagic waters and analysing related PKS genes, this study identified *Vibrio* as an EPA producer in mesopelagic seawater of the Bay of Biscay (ENA accession no. SAMEA7314594, bioproject PRJEB36532), and generated a database of *pfaA*-KS sequences (NCBI GenBank accession no. MN991210 to MN991224) that will be used for subsequent screening in marine metagenomic databases.

2.4.2 Data

Sequence data

In the context of Task 5.3, WP5 will analyse the diversity of mesopelagic marine microorganisms with potential for omega-3 fatty acid and secondary metabolite synthesis by bioprospecting available metagenomic databases.

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For this purpose, the screening of the Tara Oceans and Malaspina databases is highly relevant, as these Circumnavigation Expeditions have produced comprehensive marine gene catalogs, including samples from the deep ocean (Acinas, 2013; Acinas *et al.*, 2019; Pesant *et al.*, 2015; Sunagawa *et al.*, 2015; ENA bioproject PRJEB402). We will search for homologs of marker genes of interest in these metagenomic databases, and in any additional relevant resource that might become available during the life time of the project.

3 Conclusions & further work

Historical data are highly relevant to address the objectives of the project SUMMER. Some data centres host data without an easily or openly accessible metadata record linked to the data. In these cases, it is only possible to find the data via networking in the research community or requesting data from repositories directly. Further efforts are needed by scientists and data repositories to make these data FAIR. For example, BODC is currently discussing with the Marine Data Archive how to make their echosounder data FAIR. Both BODC and PANGAEA are in contact with European Marine Observation and Data Network (EMODnet) to enable feeding their data into their portal.

Raw acoustic data (e.g. narrowband and broadband echosounder observations) are very large (> TBs). The research community needs to agree on universally accepted data processing techniques and data products (e.g. gridded backscattering intensity). Until this happens, we must archive raw data to prevent data loss and maintain data integrity.

Archiving and publishing of historical data will continue during Task 1.3. For example, the Institute of Marine Research aims to supply a selected set of DeepVision data (video observations from the cod-end of a pelagic trawl), as well as associated acoustic data and taxonomic data from the trawl samples. The University of La Rochelle is in the process of cleaning up and compiling biodiversity data from historical trawls which will soon be made available and published on PANGAEA. Task 1.2 and D1.2 provide a basis for Task 1.3, which will produce a synthesis of SUMMER research outputs in an open access data journal.

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