

A global consistent database of plankton and detritus from in situ imaging by the Underwater Vision Profiler 5

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Abstract. Plankton and detritus are essential components of the Earth's oceans influencing biogeochemical cycles and carbon sequestration. Climate change impacts their composition and **fluxes, and** marine ecosystems as a whole. To improve our understanding of these changes, standardized observation methods and integrated global datasets are needed to enhance the accuracy of ecological and climate models. Here, we present a global dataset for plankton and detritus obtained by two versions (**SD and HD**) of the Underwater Vision Profiler 5 (UVP5). This release contains the images classified in 33 homogenized categories, as well as the metadata associated with them, reaching 3,114 profiles and ca. 8 million objects acquired between 2008-2018 at global scale. The geographical distribution of the dataset is unbalanced, with the Equatorial region (30° S - 30° N) being the most represented, followed by the high latitudes in the northern hemisphere and lastly the high latitudes in the Southern Hemisphere. Detritus is the most abundant category in terms of concentration (90%) and biovolume (95%), although its classification in different morphotypes is still not well established. Copepoda was the most abundant **planktonic taxon, followed by Trichodesmium colonies.**

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47 The two versions of UVP5 have different imagers, resulting in a different effective size range to analyze plankton and
 48 detritus from the images (HD objects >600 µm, SD objects >1 mm) and morphological properties (grey levels, etc.);
 49 however, both systems capture comparable qualitative patterns in object morphology and relative abundance across
 50 size classes, even though the absolute ranges differ. Therefore, recommendations are provided for the appropriate use
 51 of this data when conducting studies. A large number of images of plankton and detritus will be collected in the future
 52 by the UVP5, and the public availability of this dataset will help it being utilized as a training set for machine learning
 53 and being improved by the scientific community. This will reduce uncertainty by identifying previously unclassified
 54 objects and expand the classification categories, ultimately enhancing biodiversity quantification. The dataset that
 55 constitutes this first release is available on SEANOE (<https://doi.org/10.17882/107583>).

56 **Key words:** plankton, images, Underwater Vision Profiler, Global Ocean

57 1 Introduction

58 Plankton and particulate matter play a crucial role in natural biogeochemical cycles and provide essential
 59 ecosystem services, including carbon sequestration, nutrient cycling, and primary food source for various marine
 60 organisms (Turner, 2015; Boyd et al., 2019; Stemmann and Boss, 2012; Steinberg and Landry, 2017). These
 61 components of the marine environment are significantly influenced by climate change, which alters ocean temperature,
 62 acidity, oxygenation, and circulation patterns (Doney et al., 2012; Constable et al., 2014). Such changes may, in turn,
 63 impact plankton composition by affecting their growth and survival (Hays et al., 2005; Dam and Baumann, 2017;
 64 Yebra et al., 2022), which will impact the production and composition of their solid waste, hereafter referred as
 65 detritus, with potential consequences for elemental biogeochemical cycles and deep-sea ecosystems (Du Pontavice et
 66 al., 2020).

67 The size range of plankton and detritus spans from pico- to macro-sizes, influencing the methods required
 68 for their observation. Collection methods include, for example, water sampling and microscopy for the smallest size
 69 classes, net tows and sediment traps for larger particles, while observation and analysis rely on complementary
 70 technologies such as optical imaging systems and remote sensing, depending on the targeted size range (Karsenti et
 71 al., 2011; Davis et al., 2005; Stemmann et al., 2008; Möller et al., 2012; Siegel et al., 2024). Consequently, obtaining
 72 homogeneous global datasets remains difficult notably if different instruments that measure various properties are
 73 used (Moriarty and O'Brien, 2013). Many planktonic organisms and detritus are fragile and their abundances decrease
 74 with their size, making their collection and analysis challenging (Stemmann et al., 2008; Soviadan et al., 2024;
 75 Atherden et al., 2024). Furthermore, plankton exhibits a patchy distribution in the ocean due to physical, chemical,
 76 and biological processes (Suthers et al., 2019). These constraints demand increased sampling efforts and the
 77 development of standardized methodologies to enhance comparability of global plankton and detritus observations.
 78 Addressing these challenges is critical for improving our understanding of oceanic carbon cycling and ecosystem
 79 responses to environmental change.

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Deleted: Zooplankton biomass and diversity, as well as bulk particulate matter, were identified as essential ocean biodiversity, and climate variables by the Global Ocean Observing System (Chiba et al., 2018; Batten et al., 2019).

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Predicting the future state of plankton biodiversity and/or biomass with habitat or biogeochemical models is difficult and requires data obtained synoptically and regularly. ~~Deep collection by net tows followed by taxonomic identification with microscopes provides accurate biodiversity data, though this sampling method damages fragile organisms and requires~~ dedicated ship time (Calbet, 2024; Saviadan et al., 2024; Giering et al., 2022). In addition, this classical classification is time-consuming and susceptible to human bias, which can hinder effective quality control (Goswami, 2004). Sensors mounted on conventional in situ platforms may provide better spatial resolution and have less impact on the observed target. In situ acoustics with broadband systems allow for broad taxonomic identification but are not adapted for detritus due to their poor scattering. For plankton, quantitative imaging has been identified as the best means to do so (Lombard et al 2019). In situ imaging methods are better suited to recognize plankton and detritus, but detect them in a smaller volume. Considering the advantages and limitations of each method, we can conclude that in situ imaging is particularly suited for observing plankton and detritus, using their shape to infer taxonomy or morphological attributes (Picheral et al., 2010; Stemmann et al., 2012; Lombard et al., 2019). However, there is a compromise between the observed volume and the resolution of the camera that defines a size range and taxonomic resolution for each type of sensor. Recent publications have suggested (Lombard et al., 2019, Kiko et al., 2023) and showcased (Drago et al. 2022, Clements et al. 2023, Laget et al. 2024) that cooperative observation of plankton with imaging systems can allow an upscaling of regional observations by independent observers to global scale.

The Underwater Vision Profiler camera system (UVP, version 5) is an optical imaging instrument designed to automatically detect, size, and count biotic and abiotic particles in the marine environment as it profiles through the water column (Picheral et al., 2010). To date, the 25 units of the UVP5 have been used at 14,462 sites since 2008 providing 94.8 millions of images and ~1,000 new profiles every year. The number of taxa that can be recognized is over 200, whereas robust data is available for the 30 most abundant taxa (Drago et al., 2022; Panaïotis et al., 2023). Semi-supervised classification (automatic prediction followed by human validation) of plankton images (Irisson et al., 2022) was performed at regional scales, because of the time required to analyze all profiles and the lack of dedicated work flow to deal with millions of images. Recently the development of the collaborative platform Ecopart (<https://ecopart.obs-vlfr.fr/>) for UVP metadata and data curation, and EcoTaxa (<https://ecotaxa.obs-vlfr.fr/>) for supervised image classification facilitated data treatment for the users. The data, initially recorded to address regional questions, can then be aggregated in global datasets to investigate global distributions of counts, size and vertical flux of all detected objects (Kiko et al., 2022; Clements et al., 2022; Clements et al., 2023). Furthermore, these platforms allow global studies on macrozooplankton biomass (Drago et al., 2022), and community composition (Panaïotis et al., 2023), as well as on the community proportions of Rhizaria (Biard et al., 2016), their impact on carbon flux attenuation, and silicification (Laget et al., 2024). To date, these studies provided the following data products: global plankton biomass, counts and group specific carbon demand data. In addition, to facilitate data access for modelers, all UVP5 particle size profiles, which were analyzed without image recognition, were released at a 1 degree spatial resolution (Kiko et al., 2022). A more recent database obtained by combining images from Imaging Flow CytoBot, Zooscan and UVP5 to provide data products on plankton and detritus biomass binned in 1 degree resolution was also released (Dugenne et al., 2024). An attempt was made to classify detritus images based on their morphology

Deleted: According to specific objectives, biogeochemists focus on biomass as a measure of carbon content, while ecologists are primarily interested in community composition and biodiversity. Conventional sampling methods such as sediment traps, nets, pumps, and bottles further contribute to these differences, as they may not provide data that is directly comparable across disciplines. Modelers, on the other hand, require integrative datasets that bridge these gaps, enabling accurate simulations of biogeochemical cycles, ecosystem dynamics, and carbon fluxes (Ratnarajah et al., 2023). They are particularly interested in harmonized data formats, conversion factors between abundance and biomass, and standardized methodologies to improve the predictive power of ecological and climate models. Addressing these disparities is essential for advancing interdisciplinary research and improving our understanding of oceanic processes.

Deleted: Models could be partially fed by Continuous Plankton Recorder surveys (Batten et al., 2019) and satellite programs, such as the recently launched PACE (Gorman et al., 2019), but in both cases data on plankton is limited to the surface layer.

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Deleted: Thus, plans are now underway to measure these variables with imaging systems on large-scale observing programs, like the Bio-GO-SHIP (Clayton et al., 2022) or the BGC-Argo (Claustre et al., 2020; Picheral et al., 2022) programs...

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Deleted: that captures digital images of a defined volume of seawater, provisioned with LED lights. It was

Deleted: The UVP5 optimal size range to identify and measure morphological traits is in the order of 600 µm to a few millimeters (Picheral et al., 2010; Drago et al., 2022).

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177 (Trudnowska et al., 2022) but given their high number and the lack of consistent shapes, their classification at global
178 scale is still challenging.

179 Here, we present the global dataset comprising approximately 8 million validated images of plankton and
180 detritus, rigorously verified by expert taxonomists, associated with relevant metadata and their morphological
181 measurements, that was not released in earlier studies. The dataset is of interest for marine ecologists interested in
182 plankton biogeography and biogeochemical modeling and for computer scientists developing Artificial Intelligence
183 methods to classify images. While the current plankton classification has been homogenized for 33 categories, there
184 remains potential for further improvement to increase the list of taxa consistent at a global scale. Classification of
185 detritus was not performed, as existing methodologies developed at regional scale must be improved for a global
186 approach. By providing the raw images for plankton and detritus, we hope to foster the development of new algorithms
187 to sort and analyze them. The manuscript is organized as follows: the Material and Methods section provides details
188 about the UVP5, the inter-calibration and quality control procedures, as well as the dataset structure. The result section
189 presents maps of the dataset distribution, summarizing statistics regarding taxa composition, size spectrum, description
190 of global detritus and plankton distribution. The Discussion section provides recommendations for dataset use and
191 potential future expansions of it.

192 2 Material and methods

193 2.1 Image acquisition with UVP5

194 2.1.1 UVP5 description

195 Data from the Underwater Vision Profiler 5 (UVP5), an in-situ imaging system designed to detect, measure,
196 and quantify the distribution of zooplanktonic organisms and marine particles (Picheral et al., 2010), were used. The
197 UVP5 was commercialized in 2010 and produced until 2021. The standard definition (SD) version with a 1.3
198 Megapixel greyscale camera was produced between 2008 and 2016 (serial numbers 000 to 011) and the high-definition
199 (HD) version with a 4 Megapixel greyscale camera was produced between 2016 and 2021 (serial numbers 200 to 223).
200 The UVP5 (SD and HD) images a volume of about 1 L at a frequency of 5 to 20 Hz and can be deployed down to
201 6000 m depth. The UVP5 is mostly integrated in the CTD-Rosette and therefore its results (particle and plankton
202 counts) can be related to environmental data obtained with other sensors. All particles larger than appr. 100 µm
203 Equivalent Spherical Diameter (ESD) are sized and counted but their images are not stored because the low number
204 of pixels precludes any recognition of the particles. Recognized objects larger than 30 pixels (UVP5SD) or 80 pixels
205 (UVP5HD) are automatically cropped and the resulting vignettes stored and further analyzed.

206 2.1.2 Image analysis by zooprocess

207 Vignettes contain plankton organisms, detritus and artefacts larger than approximately 1 mm ESD for
208 UVP5SD and 600 µm for UVP5HD. Pixel size-to-millimeter conversions for UVP5SD and UVP5HD are derived

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Deleted: 2.1 Sampling sites
Data from the Underwater Vision Profiler 5 (UVP5), an in-situ imaging system designed to detect, measure, and quantify the distribution of zooplanktonic organisms and marine particles (Picheral et al., 2010), were used. The UVP5 dataset (Figure 2) was compiled from observations across all oceans over a 10-year period (2008–2018) through a collaboration of international partners. It includes 3,114 profiles from 62 EcoTaxa projects conducted during research cruises by different institutions (Table A1), each aimed at addressing specific local or basin-scale research questions.

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240 from objects of 30 and 80 pixels, respectively. For simplicity, we converted the surface area in pixels to its Equivalent
241 Spherical Diameter. In addition, the released dataset contains 42 morphological features characterizing each object
242 (area, major and minor axis, grey level etc.; Picheral and Mériquet, 2026) obtained from the segmentation of raw
243 vignettes. Metadata collection (geographic location, date, etc.) and processing of all 8.46 million images was carried
244 out using the ZooProcess software. For user convenience, the images were inverted to show dark objects on a white
245 background and a scale bar was added to each vignette. Images and metadata were imported into EcoTaxa (Picheral
246 et al., 2017), an application which allows a taxonomic classification of images via supervised learning algorithms,
247 followed by manual validation (Irisson et al., 2022).

Deleted: The processing included the segmentation of the object from the obtained raw vignette and the measurement of 42 morphological features associated with each object (area, major and minor axis, grey level etc.; Picheral and Mériquet, 2025; Table A2).

248 The two versions of the UVP5 have been inter-calibrated based on the size spectrum of all particles measured
249 concurrently in natural conditions (Kiko et al., 2022). Therefore, size is a conservative property between the
250 instruments and plankton community composition can be inter-compared. While all parameters, except for shape-
251 based ones, differ between the SD and HD versions due to the distinct resolution of their imagers, other morphological
252 properties, such as opacity, brightness, etc., may not be conservative, requiring caution in their joint analysis. For the
253 HD version, measurements are taken from images with a dark field, which are then converted to a light field
254 comparable to those in the SD version. Additionally, only images from a continuous descent of the instrument were
255 retained. Beyond the SD/HD distinction, individual UVP5 units were operated with different acquisition settings, so
256 their outputs are not directly comparable. In particular, the distribution of morphological features from unit sn000
257 differs from that of the other serial numbers. Users should therefore consider a correction before pooling data across
258 units; a quantile-to-quantile transformation (code in Appendix B) should be applied to adjust the distribution profile
259 of sn000 to match the other serial-number settings.

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260 **2.1.3 Semi-automatic image identification**

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261 Using EcoTaxa (<https://ecotaxa.obs-vlfr.fr/>), we applied semi-automated recognition in two steps following
262 the third strategy path defined in Figure 2 by Irisson et al. (2022). First, features obtained using Zooprocess software
263 or features re-calculated by a convolutional neural network (CNN) are considered to automatically predict object
264 identities using a Random Forest algorithm. Therefore, various image learning sets were used independently on a
265 project-by-project basis by different users. In this way, plankton organisms can be successfully classified into a few
266 broad categories from the overdominant category of detritus with reasonable success. In a second step, manual
267 validation and further sorting ensured correct classification of all plankton categories and detritus. In general, the
268 sorting was performed by various users and institutions. To reduce the risk of wrong identification, a shared UVP5
269 taxonomic guide was used by all annotators to homogenize image sorting (EcoTaxaGuide application). In addition,
270 annotations were rigorously quality checked by the authors. The classification of all images was strictly based on the
271 morphological features of the objects in most cases. However, few annotators have used contextual information
272 provided by other means (e.g., bottle or net collections, depth, GPS position) to classify objects with inadequate
273 morphological attributes into taxa. For example, colonies of *Trichodesmium* (-contextual) can be reliably identified in

281 images when their presence is confirmed by concurrent bottle samples or net tows, even when their morphological
282 features alone are insufficient for unambiguous classification.

283 2.2 Dataset

284 The UVP5 dataset (Figure 2) was compiled from observations across all oceans over a 10-year period (2008–
285 2018) through a collaboration of international partners. It includes 3,114 profiles from 62 EcoTaxa projects conducted
286 during research cruises by different institutions (Table A1), each aimed at addressing specific local or basin-scale
287 research questions. It comprises vertical profiles validated to more than 99%, which were retained for subsequent
288 analysis. Currently, the different annotators (in total 71, Table A3) of the 62 EcoTaxa projects chosen have sorted the
289 image datasets in more than 250 categories from species level to phyla or by adding morphological attributes and life
290 stages. Such detailed classification is not possible over the whole dataset with high accuracy because recognition and
291 sorting of organisms can be a source of bias depending on the levels of perception and experience of the people who
292 perform them. Several cognitive biases exist, such as boredom, fatigue or a classification biased towards the most
293 used groups (Culverhouse, 2007; Culverhouse et al., 2014).

294 In the present dataset, to reduce these errors and ensure classification homogeneity, the images were
295 thereafter grouped into only 33 broader taxonomic groups for living organisms by combining all vignettes within the
296 children categories (Table 1), while in EcoTaxa the original categories are maintained. The broad taxonomy list was
297 established following recent published works using UVP5 data (Drago et al., 2022; Panaïotis et al., 2023; Laget et al.,
298 2024) to ensure a minimum of 50 images per category and ecological patterns at regional or global scales for specific
299 groups or community composition. For example, rhizarians were well studied at local (Biard and Ohman, 2020) and
300 global scales (Biard et al., 2016; Laget et al., 2024) while polychaetes were mostly studied in the tropical Atlantic
301 (Christiansen et al., 2018). Community composition analyses have been conducted at local scales by Forest et al.
302 (2012) and Barth et al. (2020), and at a global scale by Panaïotis et al. (2022). Global biomass was estimated in Drago
303 et al. (2022). Inter-comparison with plankton net data at global scale (Soviadan et al., 2024) allowed to set confidence
304 in the abundance assessments of many of these groups.

305 Images of unidentifiable objects exhibiting probable biological characteristics (e.g., symmetry, appendages,
306 or tentacles) were classified into the “plankton-like” category. In this dataset, the term “-like” refers to structured
307 objects that resemble organisms but cannot be taxonomically identified due to limitations such as poor focus, low
308 resolution, incomplete capture, or lack of taxonomic knowledge. For example, copepoda-like contains all vignettes of
309 copepods for which the antenna is not visible while the body shape resembles typical prosome and urosome. When
310 recurring objects that were not yet classified appeared frequently but with uneven spatial distribution, temporary
311 categories were created to accommodate them and labeled as temporary (tmpXXX). When contextual information to
312 identify them was used, “contextual” was added to their names. All images of non-living organisms, including poor-
313 quality images (blurred, low grey level, bubbles, artificial nature, badly segmented images) or particles (aggregates,
314 fibers, pellets) were sorted into several categories without consistency criteria across the consortium. Low-quality

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Deleted: Thus, the term -like in this dataset refers to all objects that have a structured morphology (appendages, symmetry) that make them resemble an organism but that can't be classified as such. This labeling includes issues due to bad focus, low image resolution, incomplete organism capture, or the unknown nature of the organisms to the annotator that hinder the accurate taxonomic identification.

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340 images (mostly objects not completely in focus) were set in a category named “artefact” that includes bad focus
341 particles, plankton and real artefact, while particles were grouped into a single detritus category.

342 To ensure data consistency across projects, a subset of the dataset was reviewed to verify the accuracy of
343 taxonomic sorting within each group. A total of 200 images were extracted from each category, or all available images
344 if fewer than 200 were present. For detritus, 10 % of the total images were selected and independently reviewed by a
345 different trained operator, working independently of the initial classification, after the final dataset was assembled.
346 The error or uncertainty rate was under 8 % for taxa classification. Among the detritus, less than 0.1 % were plankton
347 organisms. The resulting global dataset consisted of 7.05 million detritus images and 734 thousand plankton images
348 from 3,114 profiles.

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349 Due to the large number of plots required to display the results for all categories, results are shown for a
350 subset of the original categories. From the 33 initial categories derived from taxonomy (Table 1), five broader
351 taxonomic groups were defined for further analysis based on shared feeding strategies and ecological traits (e.g.
352 habitat, life mode, and trophic role). These groups can be highly useful as input for biogeochemical or community
353 ecology models. The groups include Crustacea (Copepoda and Malacostraca), gelatinous filter-feeders
354 (Appendicularia, Salpida), gelatinous carnivores (Chaetognatha, Narcomedusae, Siphonophorae, Ctenophora),
355 Rhizaria (Collodaria, colonial Collodaria, other Rhizaria, Foraminifera, Phaeodaria, Acantharea), and *Trichodesmium*.
356 From these groups, biovolumes were calculated along with concentrations at different depths, and for the analysis of
357 the average grey level.

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358 2.2.1 Data output format

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359 We provide four tables with numerical data (in .tsv format), as well as all images (with .jpg extension) while
360 their full description is available in the information documents (UVP5_dataset_organization.txt) during the download.
361 Briefly, ‘objects.tsv’ is the data table which contains each object information. The three first columns refer to the
362 unique object ID given by Ecotaxa, original object classification in Ecotaxa and object classification according to
363 Table 1. The following 42 columns contain all the object features obtained from the image (see Table A2). The
364 ‘samples.tsv’ file is the table with the metadata corresponding to all the coordinates (latitude, longitude, date and time)
365 and acquisition details (pixel size and UVP model). The ‘samples_volume.tsv’ is a table that contains the volume of
366 water in which the object was extracted and that is used to calculate concentrations (middle depth bin and volume
367 imaged). Finally, ‘properties_per_bin.tsv’ is a table with concentrations, biovolume, average size (ESD) of the 33
368 consistent categories per depth bin and per sample. The native size bin of the dataset is 5 m, but to reduce the size of
369 the file and avoid too many zeros, we provide 25 m depth bins in the surface ocean (down to 200 m depth), 50 m depth
370 bins (down to 500 m depth), 100 m bins (down to 1000 m depth) to 250 m below 1000 m. We provide the code in R
371 to recalculate the table with a depth bin of 5 m. The two files ‘ODV_biovolumes.txt’ and ‘ODV_concentrations.txt’
372 contains the same information as ‘properties_per_bin.tsv’ but in the ODV format.

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384 Table 1: List of categories that are quantitatively consistent in this work and names of children categories not homogeneous
385 among the projects. Categories also defined by their morphotypes or life stages are in bold. The published dataset contains
386 both the broad and the children categories (when more than 50 vignettes were available for the category). When available
387 publications using the dataset at regional scales are listed. Exponent numbers denote the association with an image example
388 in Figure 1.

Broad categories	Children categories	Reference
Acantharia ¹		
Actinopterygii ²		
Annelida ³	<i>Alciopidae</i> , <i>Phyllodocidae</i> , <i>Tomopteridae</i> , <i>Acrociridae</i> , <i>Flota</i> , <i>Poebius</i>	Christiansen et al., 2018; Barth and Stone, 2022
Appendicularia ⁴	body, house	Forest et al., 2012
Bacillariophyta-contextual ⁵	All objects classified as such using contextual data	
Chaetognatha ⁶	tail<Chaetognatha, head<Chaetognatha	Forest et al., 2012; Barth and Stone, 2022
other Collodaria ⁷	Solitaryblack, solitaryglobule	Biard and Ohman, 2020
colonial Collodaria ⁸		Biard and Ohman, 2020
Copepoda ⁹	like<Copepoda, Eucalanidae, like<Temoridae, ovigerous, ovigerous_side, ovigerous top-bottom, Pseudocalanus, Harpacticoida	Forest et al., 2012; Vilgrain et al., 2021; Barth and Stone, 2022
Ctenophora ¹⁰	Beroida, Cestidae, Lobata, tentacle<Ctenophora	Forest et al., 2012
Doliolida ¹¹		
Eumalacostraca ¹²	Amphipoda, Pleuroncodes, Euphausiacea, Munnopsis	Forest et al., 2012; Barth and Stone, 2022
Foraminifera ¹³		
Gasteropoda ¹⁴	Gymnosomata, Limacinidae, Creseidae, other Thecosomata	
Narcomedusae ¹⁵	<i>Solmundella bitentaculata</i> , Solmaris	
Nostocales ¹⁶	Aphanizomenon, Dolichospermum, Nodularia	
Ostracoda ¹⁷		Barth and Stone, 2022
Phaeodaria ¹⁸	Castanellidae, Circoporidae, Tuscaroridae, Aulacanthidae, <i>Aulacantha</i> , <i>Aulographis</i> , <i>Coelodendrum</i> , <i>Coelographis</i> , <i>leg</i> <Coelodendridae, Medusettidae, Aulosphaeridae, <i>Aulattractus</i> , colonial<Aulosphaeridae, like<colonial, Cannosphaeridae, colonial<Cannosphaeridae	Biard and Ohman, 2020
Pyrosoma ¹⁹		
Salpida ²⁰		
Siphonophorae ²¹	part<Siphonophorae, tentacle<Siphonophorae	
Trachymedusae ²²	Halicreatidae, <i>Aglantha digitale</i>	

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<i>Trichodesmium</i> ²³	Puff, Tuff	Guidi et al., 2012; Sandel et al., 2015	Deleted: (88,676)
<i>Trichodesmium-contextual</i> ²⁴	all objects were classified as such by using contextual data, 95% are from the same cruise	Dupouy et al., 2018	Deleted: (41,936)
other Cnidaria ²⁵	Ceriantharia		Deleted: (46,740)
other Crustacea ²⁶	larvae<Crustacea, tail<Crustacea		Deleted: (98,956)
other Hydrozoa ²⁷	Leptothecata		Deleted: (1,994)
other Mollusca ²⁸	veliger		Deleted: (74)
other Rhizaria ²⁹	contains plankton resembling to Rhizaria		Deleted: (4,569)
tentacle of Cnidaria ³⁰			Deleted: (58)
plankton-like ³¹	contains all structured objects most probably living organisms, which are in multiple categories to check, possibly plankton, to resort, other living and to rename		Deleted: (122)
detritus ³²	contains particles such as aggregates, filaments, mucus net which are not yet sorted	Trudnowska et al., 2021	Formatted: Font: Not Italic
Artefact ³³	bubble, turbid		Formatted: Font: Not Italic
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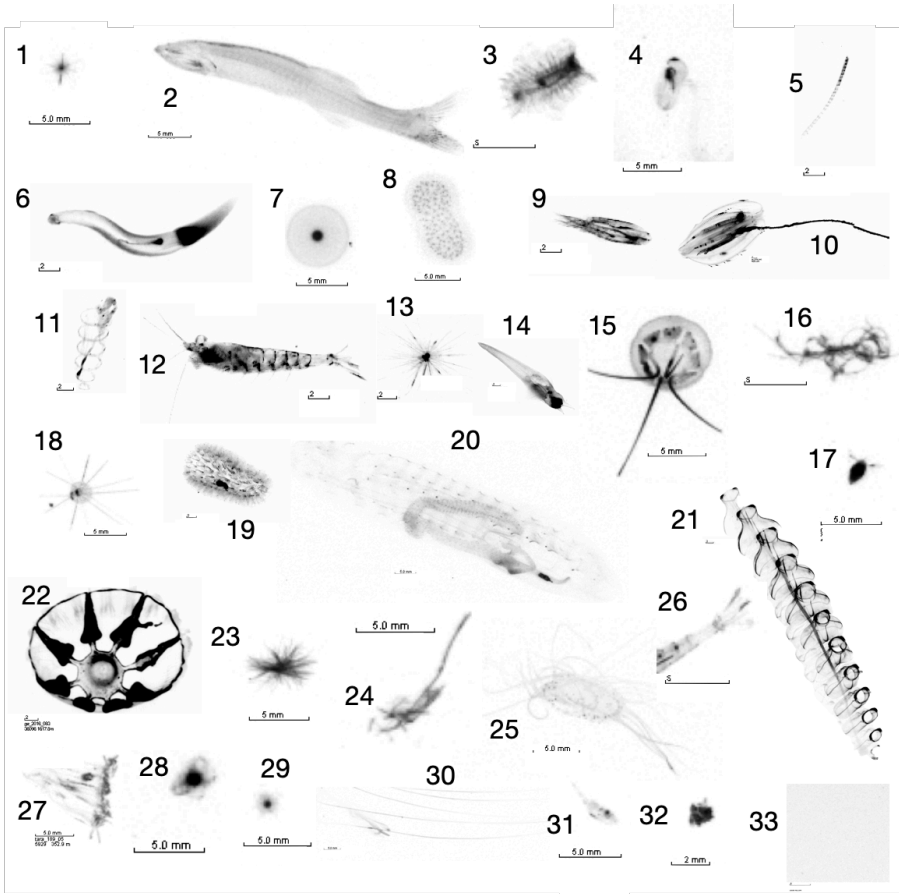


Figure 1: Examples of images for each category (Table 1) present in the dataset. All images contain the same scale bar (5 mm) which appears very small for large objects.

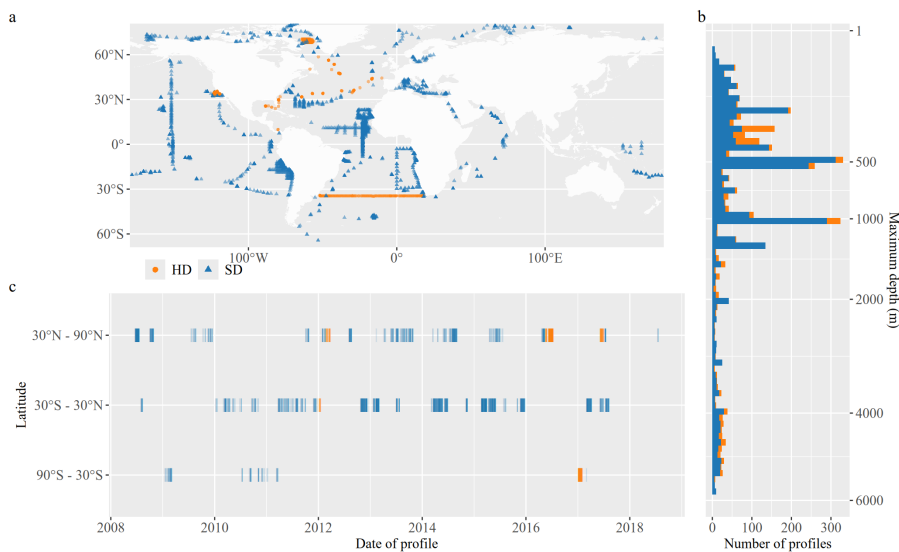
3 Results

3.1 Data coverage in time and space

The dataset presented here revealed a heterogeneous global distribution. The UVP5 deployments predominantly occurred in the northern hemisphere (66.3% of profiles, Figure 2), especially in tropical and temperate latitudes where seasonal variations are well observed. In contrast, the southern hemisphere had fewer observations (33.7% of profiles), resulting in a less comprehensive dataset. The region between 30° S-30° N represented the highest proportion of UVP5 profiles (47.25%). The vertical profiles distribution revealed a predominant concentration of

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598 measurements in the upper 1000 m of the water column, representing 40.6% and 46.8% for the SD and HD models
599 respectively, with a peak occurring within the upper 500 m. Thus, most deployments targeted shallower depths. The
600 SD version of the UVP5 demonstrated the most extensive coverage, with profiles spanning the entire latitudinal range.
601 Meanwhile, the HD profiles were prevalent in the Northern Hemisphere. The profiles also presented a remarkable
602 annual and interannual variation observed primarily in the northern hemisphere and the under-sampling of the southern
603 hemisphere and the deep sea.



604 **Figure 2: a) Sampling effort for the two versions of UVP5 (SD and HD, blue and orange, respectively) between 2008-2018**
605 **in the global ocean, b) Latitudinal distribution of UVP5 profiles and c) Maximum vertical extent of the profiles.**
606

607 3.2 Detritus and plankton composition in the whole dataset

608 Detritus was the most abundant category (90.5% of total images), indicating a substantial presence of non-
609 living particulate organic material (Fig. 3). Copepoda dominated zooplankton (2.2%), followed
610 by *Trichodesmium* (1.3%), *Trichodesmium*-contextual (1.1%), the plankton-like category (1%), artefacts (0.9%),
611 *Phaeodaria* (0.8%), and *Bacillariophyta*-contextual (0.6%). Each of the remaining groups represent < 0.16% of the
612 total number of objects.

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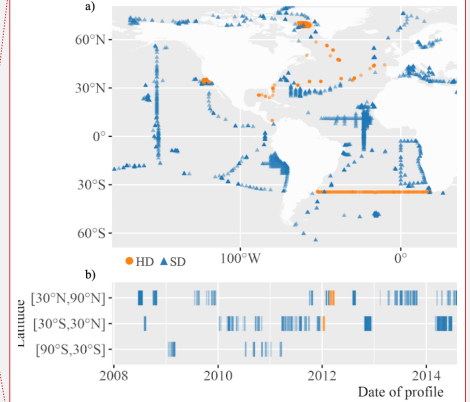
Deleted: Importantly, the two versions were rarely co-located in space and time, preventing meaningful inter-comparison of zooplankton community composition. These patterns provide valuable insights into the sampling strategies and data representation of UVP5 profiles across the global ocean.

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Deleted: Figure 3 presents the relative abundance of dataset categories, with the six most prevalent in decreasing order being: detritus, Copepoda, *Trichodesmium*-contextual, *Trichodesmium*, plankton-like, and *Phaeodaria*. Detritus is the most abundant category by far (90.5% of total images), indicating a substantial presence of non-living particulate organic material. Copepoda dominates the zooplankton and represents a significant fraction of the dataset (2.2%), followed by *Trichodesmium* (1.3%) and the *Trichodesmium*-contextual (1.1%) categories. The category plankton-like reflecting some level of taxonomic uncertainty in the dataset, is the fourth category in terms of images within the dataset (1%). The artefact category, including bubbles and artefact, occupied the sixth position (0.9%). This category is fo... [38]

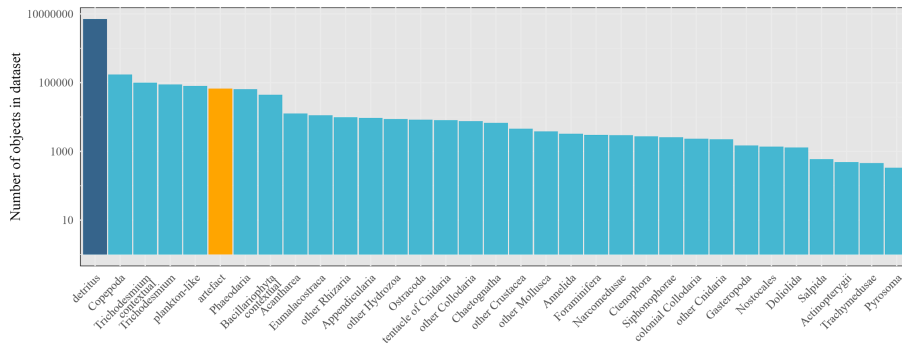


Figure 3: Barplot with total number of objects in logarithmic scale available in the dataset per category (detritus and plankton) for the 33 consistent categories ordered by descending count, with specific categories ("detritus" and "artefact") highlighted in distinct colors.

3.3 Global distribution of plankton and detritus

The spatial patterns of plankton and detritus concentrations in the global ocean vary significantly with depth and location. Across all depth layers, plankton and detritus abundances increased (up to 5 plankton/m³ and 60 detritus/m³ in the 0-100 m depth layer and up to 2 plankton/m³ and 20 detritus/m³ in the 500-1000 m depth layer, Figure 4) in eastern boundary current systems (especially in the Californian and Senegal upwelling systems) or in coastal seas. Minimum values (up to 2 plankton/m³ and 20 detritus/m³ in the 0-100 m depth layer and up to 1 plankton/m³ and 1 detritus/m³ in the 500-1000 m depth layer) were usually found in the center of large ocean gyres (notably in the South Pacific and the Indian Ocean).

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Deleted: Note that the artefact category represented here contains all vignettes including turbid, bubbles, badfocus (see section 2.3.1).

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Deleted: . Figure 4 depicts the global distribution of abundances in three depth layers

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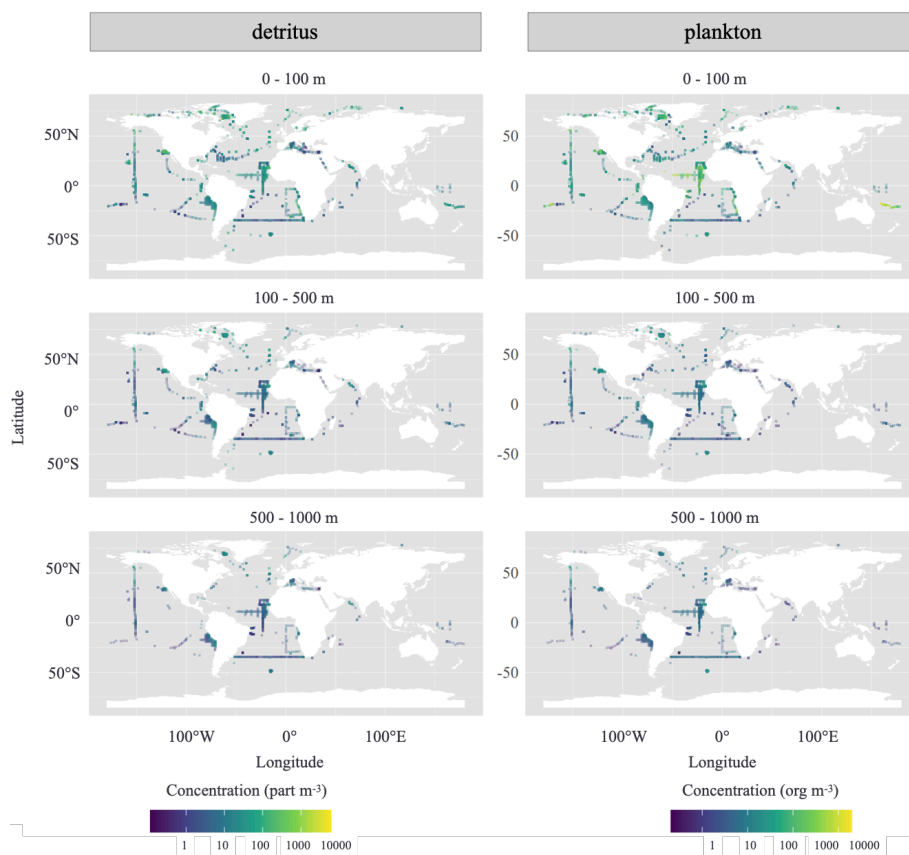


Figure 4: Map of the global distribution of detritus and plankton concentration (log particles/organism m^{-3}) in three layers (0-100, 100-500 and 500-1000 m).

3.4 Average size distribution of SD and HD versions

The distribution of detritus followed a dome-like pattern (criteria from Drago et al., 2022), with UVP5 showing a lower detection threshold for particles below 1 mm for UVP5 SD and 600 μm for UVP5 HD (Figure 5). In contrast, plankton categories exhibited a much flatter normalized biomass/biovolume size spectra (NBSS) distribution. Detritus dominated the smaller size range (<1 mm) while the contribution of plankton increased relative to detritus in the larger size range. Except for Rhizaria, smaller planktonic organisms were more abundant in the upper 100 m in the UVP5HD dataset, emphasizing the detection limits of the two camera versions in the small size range for both plankton and detritus.

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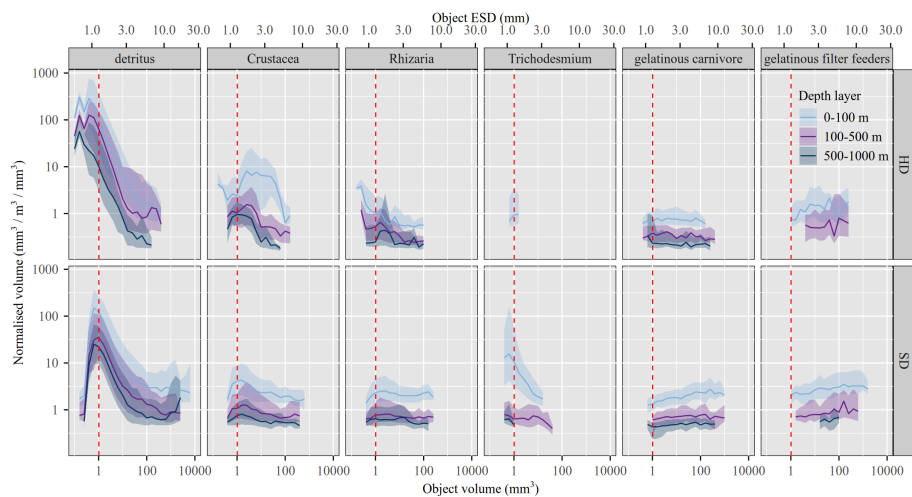


Figure 5: Average size distribution of detritus and plankton categories obtained by the SD and HD version of the UVP5 in three depth layers. Red dashed line indicates the threshold value (1.02 mm) below which UVP5 detection of organisms is difficult to quantify properly. Crustacea (Copepoda and Malacostraca), gelatinous filter-feeders (Appendicularia, Salpida), gelatinous carnivores (Chaetognatha, Narcomedusae, Siphonophorae, Ctenophora), Rhizaria (Collodaria, colonial Collodaria, other Rhizaria, Foraminifera, Phaeodaria, Acantharea), and Trichodesmium.

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3.5 Plankton to detritus ratio as a function of size

For both UVP5s, the proportion of plankton images on all images (detritus and plankton) increased with size from 0.01 at 500µm to about 0.8 for objects larger than 3 mm in ESD. The two instruments displayed a similar pattern with a plateau in this ratio starting at about 3 mm. In general, the ratio did not vary with depth and remained at 0.8 for objects larger than 3mm.

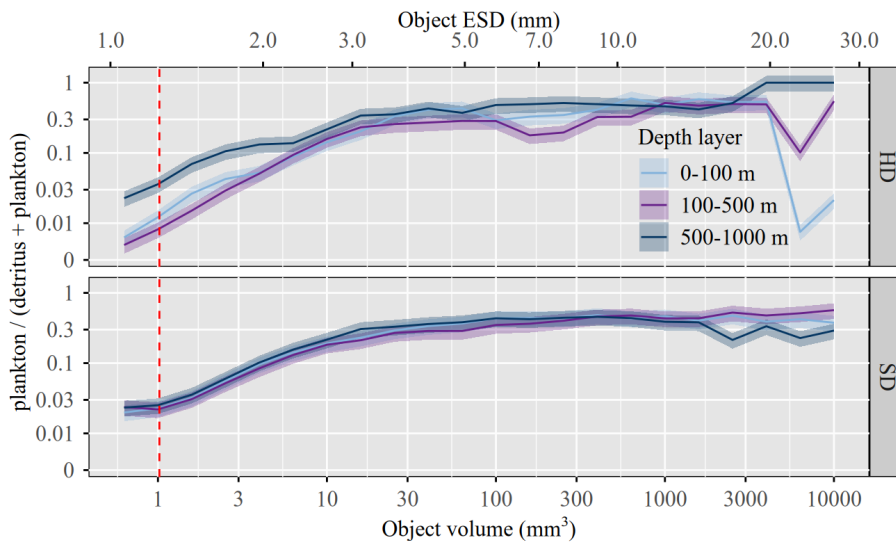
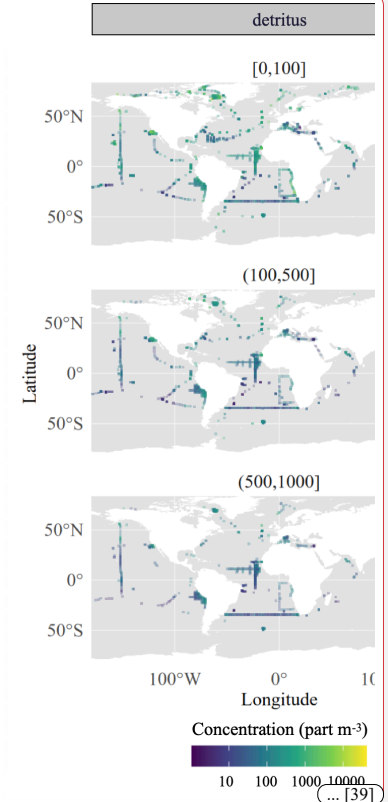


Figure 6: Abundance ratio of plankton (without plankton-like) over all images as a function of size for the two different UVP5 versions. Red dashed line indicates the threshold value (1.02 mm) below which a robust detection of organisms is limited.

3.6 Vertical profiles of detritus and plankton concentrations

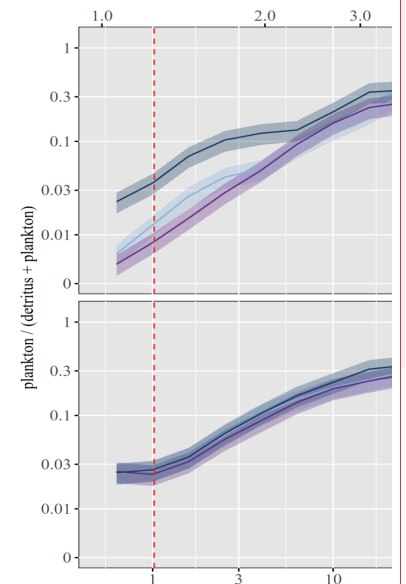
When analyzed across vertical layers (Figure 7), detritus showed the highest concentrations in the upper 100 m, with biovolume patterns mirroring concentrations and exceeding those of living plankton by several orders of magnitude. *Trichodesmium* (excluding *Trichodesmium-contextual*) was the most abundant group in surface waters, but contributed relatively little to biovolume due to its small size (Figure 4). Crustacea displayed comparable patterns in concentration and biovolume, with high surface abundance and decreasing values with depth. Gelatinous plankton, including filter feeders (*Appendicularia*, *Salpida*) and carnivores (*Chaetognatha*, *Narcomedusae*, *Siphonophorae*, *Ctenophora*), were characterized by low concentrations but disproportionately high biovolume, particularly in the upper 100 m, with both metrics declining with depth. Rhizaria also peaked in concentration and biovolume in surface waters and decreased gradually down to 1000 m.



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Moved up [6]: Figure 5: Average size distribution of detritus and plankton categories obtained by the SD and HD version of the UVP5 in three depth layers. Red dashed line indicates the threshold value (1.02 mm) below which UVP5 detection of organisms is difficult to quantify properly. Crustacea (Copepoda and Malacostraca), gelatinous filter-feeders (*Appendicularia*, *Salpida*), gelatinous carnivores (*Chaetognatha*, *Narcomedusae*, *Siphonophorae*, *Ctenophora*), Rhizaria (*Collodaria*, colonial *Collodaria*, other Rhizaria, *Foraminifera*, *Phaeodaria*, *Acantharea*), and *Trichodesmium*.

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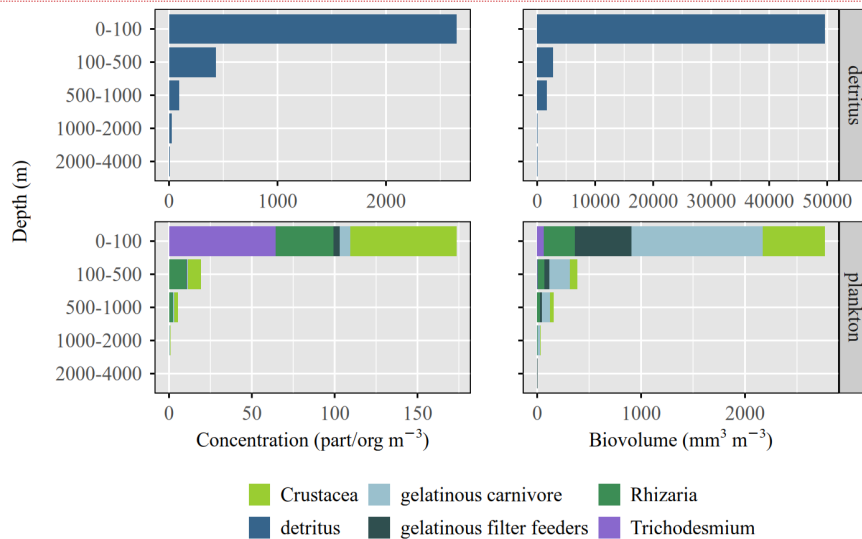
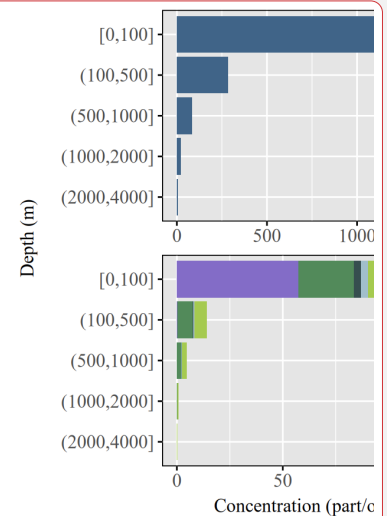


Figure 7: Global vertical profiles of concentration and biovolume for detritus and the five plankton groups. part: particles of detritus; org: organisms from different taxa categories. Crustacea (Copepoda and Malacostraca), gelatinous filter-feeders (Appendicularia, Salpida), gelatinous carnivores (Chaetognatha, Narcomedusae, Siphonophorae, Ctenophora), Rhizaria (Collodaria, colonial Collodaria, other Rhizaria, Foraminifera, Phaeodaria, Acantharea), and *Trichodesmium*.

3.7 Morphological properties

The key morphological properties for detritus and the five plankton categories presented similar patterns between the two UVP5 versions (SD and HD) (Figure 8). In some cases, the range differed between versions for the groups depending on the property examined. Gelatinous groups were the biggest categories in terms of area measured, while they presented the lowest circularity, compared to the remaining groups. Crustacea was the darkest group, whilst gelatinous were the lightest ones.



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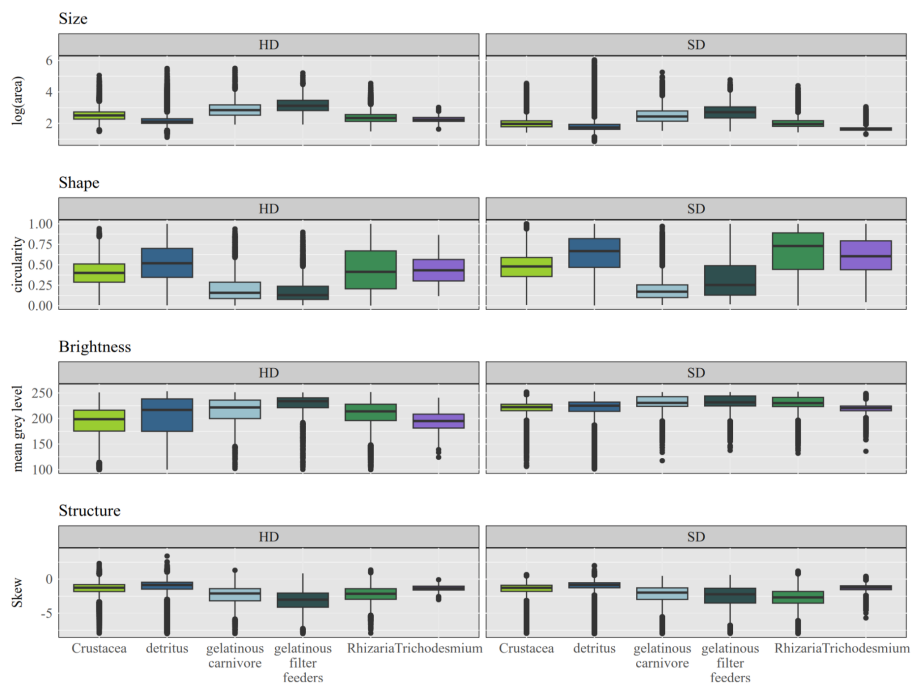


Figure 8: Box plots of key exemplary morphological properties (area, circularity, mean grey level, skew) for detritus and the five taxonomic groups (Crustacea, gelatinous carnivore, gelatinous filter feeders, Rhizaria and *Trichodesmium*) for the two UVP5 versions (HD and SD). Crustacea (Copepoda and Malacostraca), gelatinous filter-feeders (Appendicularia, Salpida), gelatinous carnivores (Chaetognatha, Narcomedusae, Siphonophorae, Ctenophora), Rhizaria (Collodaria, colonial Collodaria, other Rhizaria, Foraminifera, Phaeodaria, Acantharea), and *Trichodesmium*.

894 4 Discussion

895 The availability and accessibility of both the UVP5 images and their associated metadata present new
896 challenges, encouraging the scientific community to leverage and refine them for future research. With this objective
897 in mind, the dataset presented here serves as a starting point for further exploration of the current database (10,000
898 profiles not fully validated) and future data incorporated in EcoTaxa (approximately 500 profiles annually on average
899 over the last three years for UVP5 versions only), covering both plankton and detritus. In this context, we discuss the
900 strengths and limitations of the dataset, as well as its potential applications and future directions for the UVP database.

901 4.1 Consideration related to spatial coverage and instruments performances

902 The dataset provides decade-long global coverage with standardized methodologies across UVP5 versions,
903 spanning all major ocean basins. However, the southern hemisphere and deep sea remain undersampled, and profiles
904 are mostly concentrated in mid-high latitude of the northern hemisphere (Figure 2). Well sampled regions correspond
905 to long-term monitoring or time-series programs, such as the California Current, the Western Mediterranean, and the
906 Equatorial region, through initiatives like the CCELT program (e.g., Biard and Ohman, 2020), ongoing
907 observational efforts of MOOSE (e.g., Llopis Monferrer et al., 2022), and long-term studies in the Equatorial region
908 (e.g., Kiko et al. 2017, Fernández-Carrera et al., 2023). The even distribution across ocean basins is mostly the result
909 of the Tara Ocean Expeditions (2009-2013). Despite broad coverage, small sampled volumes can limit detection of
910 rare taxa, affect image based identification, and cause “zeros” that may reflect detection limits rather than true absence.

911 At larger size ranges, rare taxa require aggregation counts across thick vertical ocean layers to achieve
912 statistical robustness (Hauss et al., 2016; Panaïotis et al., 2023). At the surface, abundant taxa may permit 10 m binning
913 intervals (Dupouy et al., 2018; Biard and Ohman, 2020), though 20 m bins are typically more appropriate (Picheral
914 et al., 2010). In this study, data were grouped into five depth layers (0-100, 100-500, 500-1000, 1000-2000 and 2000-
915 4000 m) balancing resolution for abundant surface taxa with sufficient counts for rare deeper organisms. While
916 previous publications have adopted fixed depth ranges of 0-200 m and 200-500 m (Drago et al., 2022), or a dynamic
917 layer, set as the deepest value among the mixed layer depth and the euphotic depth (median 88 m, Panaïotis et al.,
918 2023), the choice of the vertical layering ultimately depends on the scientific question.

919 The two UVP5 versions are inter-calibrated based on the size spectra from repeated joint profiles (Picheral
920 et al., 2010; Kiko et al., 2022). Users should also account for unit-specific settings: sn000 (used, for example, during
921 Tara Oceans 2009-2012) shows a different distribution of features and may require a quantile-to-quantile
922 transformation, or exclusion, in cross-unit analyses. Detection efficiency varies with object size (Figure 5), where HD
923 version captures detritus <1 mm more effectively than the SD version, while both perform similarly above 1 mm. Size
924 spectra generally show a peak at the detection limit, a steep decline for intermediate sizes, and a flatter distribution for
925 large objects (Stemmann and Boss, 2012).

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992 4.2 Considerations related to classification

993 Variations in the depth of taxonomic classification among annotators necessitated the merging of certain
994 groups, resulting in a final list of 33 taxa at the lowest common taxonomic denominator (Table 1). To validate
995 classification accuracy, a random subset of images (200 from each taxon and 10,000 for detritus) was independently
996 reviewed by a single operator. Error rates were consistently below 10% across all groups, with most groups exhibiting
997 error rates under 2.5%. A source of error in the case of detritus is that many annotators had moved un-focused particles
998 into the category artefact. This category includes images of objects arising from external or procedural factors.
999 Examples of such artifacts include reflections or shadows from a poorly tied rope, presence of seals near the camera,
1000 cables, or other non-biological objects inadvertently captured during image acquisition, as well as badly segmented
1001 objects in nepheloid layers that modify the background. On the other hand, it may also consist of effects like bubbles
1002 caused by the descent through the air/water interface where bubbles are captured on the hardware, as well as artifacts
1003 resulting from image blurriness where no actual object or non-recognizable object is present (real artifact). When
1004 analyzing the artefact category which contains some subjectivity, considering for example that bad-focused could be
1005 very transparent objects, we found that it consists of 85% of real detritus shaped objects, 5% of plankton and 10% of
1006 artefact. Sorting them in the EcoTaxa database system would be too time-consuming, so users must decide whether
1007 to include or exclude them during the analysis. Here, we merged them with detritus as they would become a minority
1008 (less than few percent). However, it is important to note that objects classified as artefacts (not shown in Figure 7)
1009 represent less than 1% of the total dataset when the concentration is calculated, but contribute to more than 200%
1010 when volume is considered. Their impact is high mostly on large objects because many artefacts are observed in very
1011 turbid water where particles are badly segmented. This highlights the significance of their removal.

1012 *Plankton-like*

1013 We have gathered in plankton-like all objects that are most probably plankton. Inside this category, ~60% of
1014 the objects in the possibly plankton group may be Rhizaria, but the image definition impairs their recognition. It is
1015 important to keep this category apart from the detritus category because they represent a significant fraction of the
1016 total plankton count and probably living biomass. Although a significant portion indicates uncertain classification, it
1017 is also in this category that most new findings can be performed.

1018 *Plankton contextual*

1019 The term -contextual in this dataset refers to objects that were classified as a taxonomic category but do not
1020 have the morphology of the taxa. Scientists on oceanographic surveys who had other contextual information have
1021 created the category *Trichodesmium*-contextual and Bacillariophyta-contextual for objects that aren't formally
1022 identified as *Trichodesmium* puff and tuff or as diatom chains. In this context, the classification is supported by many
1023 other optical observations (for example see Dupouy et al., 2018 for *Trichodesmium*). Due to the risk of mis-interpreting
1024 ecological results or impairing the quality of the learning set, it is better to distinguish them from objects whose images
1025 are typical of plankton organisms. In the case of the two categories, *Trichodesmium* and *Trichodesmium*-contextual,
1026 they contain nearly the same number of objects, so including both would double the amount of data for this group. On

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the other hand, Bacillariophyta-contextual represents the sole category for this genus within the dataset, where its inclusion or not could lead to its complete exclusion.

4.3 Scientific relevance

Overall, this dataset provides a unique and comprehensive tool for the scientific community, enabling researchers to examine the intricate relationships between plankton, detritus, and ecosystem function. The detailed classification of plankton and detritus provides a valuable resource for understanding the complexity between their abundance distribution and the environmental processes happening at global (Drago et al., 2022; Panafotis et al., 2023; Laget et al., 2024) and local scales (see references in Table 1) within marine systems. By analyzing the abundance, diversity, and distribution of planktonic organisms, researchers can gain insights into food web structures, energy flow, and the interactions between different trophic levels (e.g., D'Alelio et al., 2016; Perhirin et al., 2025). The data allows ecologists the monitoring of plankton communities, which are essential indicators of environmental health and can reflect changes in water quality, nutrient levels, and ecosystem productivity (Muller-Karger et al., 2018). The dataset is equally valuable in biogeochemical studies, so researchers can better predict how changes in plankton community composition and detritus abundance influence nutrient cycling and the overall functioning of marine ecosystems. Additionally, biogeochemical models that integrate this dataset can help refine predictions of carbon sequestration in the ocean, an essential process for regulating atmospheric CO₂ levels and mitigating global warming. As plankton and detritus play pivotal roles in the ocean's carbon pump, understanding their distribution in different environmental conditions is crucial for assessing the resilience of marine ecosystems and their ability to mitigate or exacerbate climate change effects (e.g., Le Quéré et al., 2016; Rohr et al., 2023). Through these integrated models, the dataset offers a robust framework for exploring the complex feedback mechanisms between marine biological communities and biogeochemical processes, advancing our ability to predict future changes in marine ecosystems under varying environmental scenarios.

4.4 Moving forward: future development

Future classification should focus its efforts on sorting the detritus category, as a recent study highlights that sinking speed estimated for various particle categories varies with particle morphology (Trudnowska et al., 2022; Soviadan et al., 2025) or that mesoscale activities mix them vertically according to their morphology (Accardo et al., 2025). In addition, they represent a very high proportion in abundance and probably of organic biomass compared to the plankton. Additionally, the specific classification of detritus particles, such as fecal pellets and their associated zooplankton communities, will enhance our understanding of their dynamics, improve the accuracy of carbon flux calculations, and refine their representation in biogeochemical models (Perhirin et al., 2025). Therefore, classifying particles based on their traits could provide valuable new insights into their origin and role in the carbon cycle through the gravitational pump (Boyd et al., 2019). When it comes to zooplankton, recent studies revealed that analyzing their traits, such as body size, morphology, and metabolic rates, which significantly influence their ecological roles and interactions within marine ecosystems, provides a framework for linking organismal characteristics to ecosystem

Deleted: ecological dynamics

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Deleted: The complex relationships between these components provide critical insights into primary productivity, nutrient fluxes, and the potential impacts of environmental stressors such as climate change and ocean acidification.

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Deleted: The published dataset (3,114 profiles, 7,000,000 images) is publicly available, while only validated images are visible from the remaining profiles in EcoTaxa (6,000 profiles, 83,000,000 images), although not yet publicly accessible to be downloaded and/or re-processed. Therefore, future users should contact the data owners through the Ecopart and EcoTaxa platforms to request access to the complete datasets.[¶] Despite the efforts of the data owners, many images in the EcoTaxa database for UVP5 were not recognized in any taxonomic group, so were categorized under a plankton-like category. The challenge of further sorting plankton-like organisms is significant due to its great abundance, but it also provides an opportunity to increase the biodiversity within the dataset and refine the taxonomy.[¶]

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1096 functions, offering deeper insights into zooplankton behavior, community structure, and their contributions to
1097 biogeochemical cycles (Titocchi et al., 2025).

1098 Transfer learning has shown promising potential in leveraging existing datasets to enhance training for
1099 improved recognition tasks. By utilizing the present dataset as a model training for machine learning and artificial
1100 intelligence (AI) techniques can be employed to better classify and extract relevant features (Lumini and Nanni, 2019;
1101 Irisson et al., 2022). Specifically, AI could play a key role in sorting and categorizing the 7,000,000 detritus images
1102 in the dataset, enhancing the processing of the remaining 5,598 UVP5 profiles and their corresponding 70 million
1103 images. Furthermore, integrating existent profiles with those acquired in the future, such as the anticipated 500
1104 annually for UVP5 and 5,000 annually for the new version of the UVP (UVP6LP and HD; Picheral et al., 2022), into
1105 the observation system will enhance the robustness of the database, ensuring its adaptability and scalability for future
1106 data handling and feature extraction. This observation effort is supported by GOOS (Dexter and Summerhayes, 2010)
1107 and already in operation in large-scale observing programs, like the Bio-GO-SHIP (Clayton et al., 2022) or possibly
1108 by the BGC-Argo (Claustre et al., 2020) program. Having better embedded classifiers is particularly important for
1109 BGC Argo for which the floats and the cameras are not recovered. The new UVP6, which can be attached or associated
1110 with different platforms, is now widespread distributed and has allowed the acquisition of innumerable profiles and
1111 87 millions of images in the last 4 years since its commercialization in 2020. These advancements will ultimately
1112 contribute to more efficient data analysis and support the continuous improvement of environmental monitoring
1113 systems.

1114 **Data availability**

1115 The dataset is available on SEANOE at <https://doi.org/10.17882/107583> (Nocera et al., 2025).

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1120 and the Research Infrastructure ILICO (CNRS--IFREMER). JOI acknowledges support by the Belmont Forum grant
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1127 Regions and Coasts in a Changing Earth System) programme of the Helmholtz Association, the INSPIRES programme
1128 of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, and the DFG Priority Program SPP

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1138 [1158 “Antarctic Research with comparative investigations in Arctic ice areas” \(project number 562122740\)](#). LS was
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1145 **Author contribution method**

1146 ACN, JOI and LS formulated the goals for dataset presentation, quality control and the publication of a global UVP5
1147 dataset and their respective images. LS and MP led the community effort supported by all UVP managers and quality
1148 control endeavours, supported by all co-authors. ACN and LS conceived and drafted the article. All authors
1149 participated in writing the article.

1150 **Conflict of interest statement**

1151 The authors declare no conflicts of interest.

1152 Appendix A

153 Table A1. List of ~~the 62~~ projects included in the present study, with ~~their~~ corresponding project identification (pprojid),
154 ~~project title indicating UVP model and serial number (ptitle), data owner, project number identification in EcoTaxa~~
155 ~~(projid), the project name (title) and license registered on EcoTaxa (<https://ecotaxa.obs-vlfr.fr/>).~~

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pprojid	ptitle	projid	title	data_owner	license
1	uvp5_sn003_jerico_2017	578	UVP5 JERICO 2017	lars.stemmann@obs-vlfr.fr	
2	uvp5_sn000_boum2008	122	UVP5 BOUM 2008	lars.stemmann@obs-vlfr.fr	
3	uvp5_sn000_ccelter_2012	45	UVP5 CCELTTER (Iter2008 ccelter_2012 ccelter_2014)	tristan.biard@univ-littoral.fr	CC BY-NC 4.0
4	uvp5_sn000_lohafex2009	109	UVP5 LOHAFEX 2009	lars.stemmann@obs-vlfr.fr	CC0 1.0
5	uvp5_sn000_lter2008	45	UVP5 CCELTTER (Iter2008 ccelter_2012 ccelter_2014)	tristan.biard@univ-littoral.fr	CC BY-NC 4.0
6	uvp5_sn000_tara2009	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
7	uvp5_sn000_tara2010	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
9	uvp5_sn000_tara2012	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
10	uvp5_sn002_moose_dyf_2013	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	lars.stemmann@obs-vlfr.fr	
11	uvp5_sn002_moose_dyf_2014	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	lars.stemmann@obs-vlfr.fr	
12	uvp5_sn002_moose_dyf_2015	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	lars.stemmann@obs-vlfr.fr	
13	uvp5_sn002_moose_dyf_2016	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	lguidi@obs-vlfr.fr	
14	uvp5_sn002_moose_dyf_2017	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	coppola@obs-vlfr.fr	
15	uvp5_sn002_moose_ge_2013	30	UVP5 MooseGE 2012 2013 2014 2015 2016	lars.stemmann@obs-vlfr.fr	CC BY-NC 4.0
16	uvp5_sn000_malina2009	28	UVP5 MALINA 2009	lars.stemmann@obs-vlfr.fr	CC BY 4.0
17	uvp5_sn002_moose_ge_2014	30	UVP5 MooseGE 2012 2013 2014 2015 2016	lars.stemmann@obs-vlfr.fr	CC BY-NC 4.0
20	uvp5_sn000_operex2008	110	UVP5 OPEREX 2008	lars.stemmann@obs-vlfr.fr	CC BY 4.0

21	uwp5_sn001_2012_moose_ge	30	UVP5 MooseGE 2012 2013 2014 2015 2016	stemmann@obs-vlfr.fr	CC BY-NC 4.0
22	uwp5_sn001_2012_msm22	593	UVP5 Geomar 2012 msm22	rkiko@geomar.de	
23	uwp5_sn001_2012_msm23	584	UVP5 Geomar 2012 msm23	rkiko@geomar.de	
31	uwp5_sn002_moose_ge_2015_filtered	30	UVP5 MooseGE 2012 2013 2014 2015 2016	lars.stemmann@obs-vlfr.fr	CC BY-NC 4.0
32	uwp5_sn002_somba_ge_2014	36	UVP5 SOMBA 2014	lars.stemmann@obs-vlfr.fr	CC BY 4.0
41	uwp5_sn003_cassiopee_2015	38	UVP5 CASSIOPEE 2015	lars.stemmann@obs-vlfr.fr	CC BY 4.0
42	uwp5_sn003_ccelter_2014	45	UVP5 CCELTER (Iter2008 ccelter_2012 ccelter_2014)	tristan.biard@univ-littoral.fr	CC BY-NC 4.0
43	uwp5_sn003_ccelter_2016	156	UVP5 CCELTER 2016	tristan.biard@univ-littoral.fr	CC BY-NC 4.0
44	uwp5_sn003_dewex_spring_2013	4	UVP5 DEWEX 2013 (spring)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
46	uwp5_sn003_outpace_2015	37	UVP5 OUTPACE 2015	lguidi@obs-vlfr.fr	CC BY 4.0
47	uwp5_sn003_sargasso_a	22	UVP5 Sargasso 2014 (sargasso_a sargasso_b)	lombard@obs-vlfr.fr	CC BY 4.0
48	uwp5_sn003_sargasso_b	22	UVP5 Sargasso 2014 (sargasso_a sargasso_b)	lombard@obs-vlfr.fr	CC BY 4.0
49	uwp5_sn003_tara2013	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
51	uwp5_sn003zp_tara2012	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
53	uwp5_sn005_dewex_2013_winter	3	UVP5 DEWEX 2013 (winter)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
54	uwp5_sn005_dy032_2015_filtered	40	UVP5 DY032 205	francois.carlotti@mio.osupytheas.fr	CC BY 4.0
55	uwp5_sn005_moose_ge_2013	30	UVP5 MooseGE 2012 2013 2014 2015 2016	lars.stemmann@obs-vlfr.fr	CC BY-NC 4.0
56	uwp5_sn008_an1304	41	UVP5 AN Arctique (an1304 an1405 an1407) part A to validate	marcel.babin@takuvik.ulaval.ca	

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57	uwp5_sn008_an1405	41	UVP5 AN Arctique (an1304 an1405 an1407) part A to validate	marcel.babin@takuvik.u laval.ca		
58	uwp5_sn008_an1406	618	UVP5 AN 1406	marcel.babin@takuvik.u laval.ca	CC BY- NC 4.0	
59	uwp5_sn008_an1407	41	UVP5 AN Arctique (an1304 an1405 an1407) part A to validate	marcel.babin@takuvik.u laval.ca		
60	uwp5_sn008_green_201 5_icecamp	42	UVP5 GREEN EDGE Ice Camp 2015	marcel.babin@takuvik.u laval.ca	CC BY- NC 4.0	
61	uwp5_sn008_green_201 6_icecamp	315	UVP5 GREEN EDGE Ice Camp 2016	marcel.babin@takuvik.u laval.ca	CC BY- NC 4.0	
62	uwp5_sn008_subice_201 4	107	UVP5 Subice 2014	stemmann@obs-vlfr.fr		
64	uwp5_sn009_2015_p16n	43	uwp5_sn009_2015_p16n	amcdonnell@alaska.edu	CC BY 4.0	
65	uwp5_sn009_2015_p16n _goa	43	uwp5_sn009_2015_p16n	amcdonnell@alaska.edu	CC BY 4.0	
68	uwp5_sn010_2014_m10 5	602	UVP5 Geomar 2014 m105	rkiko@geomar.de		
69	uwp5_sn010_2014_m10 6	595	UVP5 Geomar 2014 m106	rkiko@geomar.de		
70	uwp5_sn010_2014_m10 7	559	UVP5 Geomar 2014 m107	rkiko@geomar.de		
71	uwp5_sn010_2014_m10 8	586	UVP5 Geomar 2014 m108	rkiko@geomar.de		
72	uwp5_sn010_2014_ps88 b	558	UVP5 Geomar 2014 ps88b	rkiko@geomar.de		
73	uwp5_sn010_2015_m11 6	589	UVP5 Geomar 2015 m116	rkiko@geomar.de		
76	uwp5_sn010_2015_m12 1	560	UVP5 Geomar 2015 m121	rkiko@geomar.de		
81	uwp5_sn201_2016_naam es_02	146	UVP5hd NAAMES02	lee.karp- boss@maine.edu	CC BY- NC 4.0	
83	uwp5_sn201_ccelter_201 7	627	UVP5hd CCELTTER 2017	tristan.biard@univ- littoral.fr	CC BY- NC 4.0	
86	uwp5_sn203_greenedge_ 2016	149	UVP5hd GreenEdge 2016	lars.stemmann@obs- vlfr.fr	CC BY- NC 4.0	

87	uvp5_sn203_greenedge_2016_1b	149	UVP5hd GreenEdge 2016	lars.stemmann@obs-vlfr.fr	CC BY-NC 4.0
92	uvp5_sn201_2017_naames_03	637	UVP5hd NAAMES03	lee.karp-boss@maine.edu	CC BY-NC 4.0
95	uvp5_sn010_2017_m135	548	UVP5 Geomar 2017 m135	rkiko@geomar.de	
99	uvp5_sn000_tara2011	579	UVP5 Tara Oceans (tara2009, tara2010, tara2011, tara2012, tara2013)	lars.stemmann@obs-vlfr.fr	CC BY 4.0
105	uvp5_sn008_ips_amundsen_2018	1165	UVP5 IPS Amundsen 2018	marcel.babin@takuvik.ulaval.ca	CC BY 4.0
109	uvp5_sn010_2014_eddy	881	UVP5 Geomar 2014 eddy	rkiko@geomar.de	
166	uvp5_sn002_moose_dyf_2018	35	UVP5 Dyfamed 2013 2014 2015 2016 2017 2018	coppola@obs-vlfr.fr	
231	uvp5_sn202_msm060_filtered	351	UVP5hd msm060 (2017)	andreas.rogge@awi.de, anya.waite@dal.ca	Copyright
236	uvp5_sn201_2018_naames_04_filtered	1252	UVP5hd Naames 04	lee.karp-boss@maine.edu	CC BY-NC 4.0

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160 Appendix B
161 Quantile-to-quantile transformation function. The R function below is recommended to be used to adjust the distribution
162 of morphological features from UVP5 version with sn000 to match that of the other serial numbers (see Section 2.1.2).
163  #' Transform the distribution of x into that of y
164  #'
165  #' @param x vector of observations to be transformed
166  #' @param y vector of observations to be matched
167  #' @param n number of quantiles to sample (more means more precise transformation)
168
169  quantile_transformer <- function(x, y, n = 1000) {
170    probs <- seq(0, 1, length.out = n)
171    qx <- quantile(x, probs = probs)
172    qy <- quantile(y, probs = probs)
173    approx(x = qx, y = qy, xout = x, rule = 2, ties = "ordered")$y
174  }

```

Deleted: Table A2. Morphological features computed for the object (not the background). Areas and/or length units are expressed in pixels.

1178 **Table A3. List of annotators involved in the classification of objects within the current UVP5 dataset.**

Annotator name	Annotator name (<i>cont.</i>)	Annotator name (<i>cont.</i>)
Alikacem Yasmine	Gawinski Christine	Panchal Aakash
Andersson Bjoern	Gremion Gwenaelle	Panaïotis Thelma
Anhaus Philipp	Guérin Sébastien	Pelletier Noemie
Arboit Genevieve	Hasnain Sarah	Perhirin Margaux
Aubry Cyril	Hauss Helena	Perron Christophe
Bansept Marc-Antoine	Hintringer Moritz	Picheral Marc
Benoît-Gagné Maxime	Irisson Jean-Olivier	Pretty Jess
Berline Léo	Jalabert Laetitia	Prondzinsky Alannah Paulina
Berrenger Hugo	Karp Boss Lee	Reimer Jody
Biard Tristan	Kiko Rainer	Renaut Sophie
Blanc Benjamin	Lafond Augustin	Rogge Andreas
Blunck Frauke	Leguen Guillaume	Singh Akanksha
Bourdin Guillaume	Lekanoff Rachel	Singh Arvind
Caray-Counil Louis	Leroux Riwan	Spahic Susanne
Chawarski Julek	Levesque-Desrosiers Felix	Stemmann Lars
Christiansen Svenja	Li Juan	Suwaki Caroline
Courchet Lucas	Lombard Fabien	Toullec Jordan
Cram Jacob	Lopez Ruben	Trudnowska Emilia
Donosó Ferez Katty	Maps Frédéric	Vilgrain Laure
Donggyun Kim	Marec Claudie	Wauthy Maxime
Drago Laetitia	Mcdonnell Andrew M. P.	
Dullaert Emma	Migotto Alvaro	
Elineau Amanda	Motreuil Solène	
Faustmann Jannik	Nagata Renato	
Fowler Victoria	Oliveira Bruna	

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