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Distribution of mesozooplankton biomass in the global ocean

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Abstract

Mesozooplankton are cosmopolitan within the sunlit layers of the global ocean. They are important in the classical food web, having a significant feedback to primary production through their consumption of phytoplankton and microzooplankton. They are also the primary contributor to vertical particle flux in the oceans. Through both they affect the biogeochemical cycling of carbon and other nutrients in the oceans. Little, however, is known about their global distribution and biomass. While global maps of mesozooplankton biomass do exist in the literature they are usually in the form of hand-drawn maps and the original data associated with these maps are not readily available. The dataset presented in this synthesis has been in development since the late 1990's, is an integral part of the Coastal & Oceanic Plankton Ecology, Production, & Observation Database (COPEPOD), and is now also part of a wider community effort to provide a global picture of carbon biomass data for key plankton functional types, in particular to support the development of marine ecosystem models. A total of 153 163 biomass values were collected, from a variety of sources, for mesozooplankton. Of those 2 % were originally recorded as dry mass, 26 % as wet mass, 5 % as settled volume, and 68 % as displacement volume. Using a variety of non-linear biomass conversions from the literature, the data have been converted from their original units to carbon biomass. Depth-integrated values were then used to calculate mesozooplankton global biomass. Global mesozooplankton biomass, to a depth of 200 m, had a mean of $5.9\,\mu g\,C\,l^{-1}$, median of $2.7\,\mu g\,C\,l^{-1}$ and a standard deviation of $10.6\,\mu g\,C\,l^{-1}$. The global annual average estimate of mesozooplankton, based on the median value, was 0.19 Pg C. Biomass was highest in the Northern Hemisphere, but the general trend shows a slight decrease from polar oceans to temperate regions with values increasing again in the tropics.

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ESSDD

5, 893–919, 2012

Mesozooplankton biomass in the global ocean

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1 Introduction

Mesozooplankton are found throughout the world's oceans. They are defined as zooplankton ranging from 200 µm to 2 cm (Sieburth et al., 1978), consisting primarily of crustacean plankton (copepods), meroplanktic larva and smaller individual gelatinous zooplankton. Mesozooplankton are traditionally sampled by towed nets with mesh sizes ranging from 200 to 333 µm (Harris et al., 2000). They feed directly on phytoplankton, microzooplankton, other mesozooplankton and detritus, have a significant feedback to primary production and are the largest contributor to the vertical particle flux in the oceans (Buitenhuis et al., 2006). Thus they are important in both the classical food web and export production; affecting the biogeochemical cycling of carbon and other nutrients in the oceans.

While global maps of mesozooplankton biomass exist in the literature (Bogorov et al., 1968; Reid, 1962), they exist only in the form of hand-drawn maps, and the original data compiled for creating these maps are not widely available, if at all. Volume 5 of the World Ocean Atlas (WOA) 2001 (O'Brien et al., 2002) was one of the first freely available, global data compilations of zooplankton biomass created. Since then, this dataset has been expanded upon in method and data content at fairly regular intervals (O'Brien, 2005, 2007, 2010). For this synthesis, data from O'Brien (2010), along with additional new data, have been processed through the new and hybrid techniques outlined in this document.

Mesozooplankton are an important group within the plankton community. While mesozooplankton and microzooplankton collection methods and biogeochemical contribution differ greatly, a distinction is not always made between the two groups in biogeochemical models that represent all zooplankton as one box, e.g. Nutrient Plankton Detritus Zooplankton (NPDZ) models. NPDZ models have been shown to underestimate the interannual variability of chlorophyll *a*, which suggests these models also underestimate decadal and century scale sensitivity of climate variability (Buitenhuis et al., 2006). Models that more closely represent our current understanding of the marine

ESSDD
5, 893–919, 2012

ecosystem are being built in an effort to address this issue. Mesozooplankton communities have been shown to exhibit decadal scale variability with climate (Beaugrand et al., 2003) and as they have an effect on both primary production and carbon export they need to be explicitly represented in biogeochemical models (Le Quéré et al., 2005). Including mesozooplankton sensitivity to climate variability on a decadal scale, in models that capture important marine ecosystem processes, should bring us closer to modeling the response and feedbacks between marine ecosystems and climate variability, which are largely unknown at present. There is a pressing need for observations that allow the development and validation of these models and mesozooplankton is a group of significant importance in this regard.

The data presented in this paper are part of a wider community effort known as MARine Ecosystem DATa (MAREDAT). MAREDAT is a collection of global biomass datasets. It contains data on the global distribution of a variety of the major plankton functional types (PFTs) currently represented in marine ecosystem models. These include bacteria, picophytoplankton, nitrogen fixers, calcifiers, dimethyl sulphide (DMS)-producers, silicifiers, foraminifera, mesozooplankton, pteropods and macrozooplankton. MAREDAT is part of the MARine Ecosystem Model Inter-comparison Project (MAREMIP) and is responsible for this compilation of observation-based global biomass datasets. The biomass data that populate MAREDAT are freely available for use in model evaluation and development, and to the scientific community as a whole.

The original mesozooplankton biomass data extracted from COPEPOD were run through standard COPEPOD translation and standardization routines (Sect. 2.1), converted to common biomass units, net mesh sizes and depth intervals (Sect. 2.2), and run through standard COPEPOD quality control routines and secondary quality control measures (Sect. 2.3). The results of the quality control routines and the gridded mesozooplankton carbon biomass data are examined and discussed in Sect. 3.

ESSDD
5, 893–919, 2012

2 Data and methods

2.1 Origin of data

Mesozooplankton biomass data were extracted from the Coastal & Oceanic Plankton Ecology, Production, & Observation Database (COPEPOD, http://www.st.nmfs.noaa.gov/copepod), a global plankton database project of the US National Marine Fisheries Service (NMFS). COPEPOD's data content comes from ongoing and historical NMFS ecosystem surveys and monitoring projects, from data rescued by COPEPOD's Historical Plankton Data Search & Rescue project (COPEPOD-SAR), from international institutional and project-based sampling programs, and from individual investigators (e.g. thesis data, individual cruises).

COPEPOD's data, including mesozooplankton data, come from a wide variety of sources and in a wide variety of formats. There is a two-phase process that allows data to be translated faithfully from original file format and variables to the COPEPOD variable definition set and data structure. In the first phase, there are procedures in place that allow the original methods and metadata documentation to be reviewed ensuring accurate representation during translation. Once the original values are available in standard COPEPOD electronic format there are two issues: (1) original units are not always comparable and (2) taxonomic resolution is not always uniform. During the second phase, common base unit values are calculated into standard units and all taxonomic data are standardized and classified into groupings. For the purposes of this synthesis all mesozooplankton biomass values have also been converted to $\mu g\,C\,l^{-1}$. For more information in relation to the treatment and standardization of data in COPEPOD, see O'Brien (2010) (http://www.st.nmfs.noaa.gov/copepod/2010).

A total of 110 datasets were used in the global mesozooplankton biomass compilation. Table 1 lists the first 30 of these datasets, ranked in order of their spatial contribution, which represent 80 % of the spatial data coverage and 80 % of the total observations. The remaining 80 datasets individually contribute less than 1 % each to the spatial coverage. The datasets in Table 1 were ranked and sorted by the number

ESSDD
5, 893–919, 2012

of monthly 1 × 1 degree grid cells (Mcells) of spatial coverage which they contributed to the global gridded fields, as opposed to ranking by number of observations. This method gives a higher ranking to the most spatially visible members in the global grid, such as the International Indian Ocean Expedition (IIOE), which is the most visible and dominant data source in the Indian Ocean. While this dataset is spatially ranked 3rd, it would be ranked 15th based only on observations. In contrast, the long running EcoMon/MARMAP data ranks 2nd in observations but ranks 13th spatially because those 35 yr of repeat sampling in the same 1 × 1 degree grid cell actually only contribute twelve monthly means (12 Mcells) each to the global grids created by this synthesis.

2.2 Data conversion

2.2.1 Biomass conversion

There are four different types of biomass within the COPEPOD mesozooplankton dataset: wet mass, dry mass, displacement volume, and settled volume, see Fig. 1. The determination of total sample biomass or biovolume, as compared to microscope-based full sample identification and enumeration, is relatively fast and simple and is the most prevalent zooplankton measurement type and method found in both historical and ongoing mesozooplankton monitoring and survey programs (O'Brien, 2010; O'Brien et al., 2011). Of the largest data contributors to the database, the ongoing NMFS survey projects EcoFOCI, CalCOFI, SEAMAP, and EcoMon/MARMAP exclusively use displacement volume, Japanese survey programs almost exclusively use wet mass, and historical sampling by Russian/Former Soviet Union (FSU) surveys use a mixture of wet mass, displacement volume, and settled volume. Dry mass data are rare, coming primarily from the most recent sampling programs (e.g. JGOFS, GLOBEC, Norwegian Sea Survey). Published equations allow these four biomass types to be converted to carbon biomass. Total carbon mass was selected as the common zooplankton biomass proxy because of its fundamental use in food chain and energy flow applications (Harris et al., 2000; Wiebe et al., 1975) and the abundance of published

ESSDD
5, 893–919, 2012

conversion equations to this biomass type (e.g. Cushing et al., 1958; Balvay, 1987; Wiebe, 1988; Bode, 1998; Harris, 2000). The non-linear biomass conversion equations of Balvay (1987), Wiebe (1988) and Bode et al. (1998) are used (Table 2).

2.2.2 Net mesh sizes

The mesozooplankton size fraction was extracted from COPEPOD by selecting only data from net mesh sizes 150 to 650 µm. Three general mesh groups occur centered on 200 µm, 333 µm, and 505 µm (Fig. 2a). Historically, the most common mesh size was 333 µm (Fig. 2b), used by large, and often continuous, monitoring programs carried out by the US and Japan and by historical multi-national projects such as IIOE and NORWESTLANT. Recently sampled data, as well as the historical Russian/FSU data, focus more on data in 200 µm mesh data (Fig. 2c). Finally, large areas of the eastern Pacific used 505 µm mesh nets for their ichthyoplankton-focused surveys (Fig. 2d). A mesh category, mCAT, was assigned to each of these groupings, labeled m200, m333, m505. The original values and the assigned mCAT values are both documented in the original mesozooplankton dataset.

Mesh size affects what is actually caught (Landry et al., 2001; Hernroth, 1987; DeVries and Stein, 1991; Colton et al., 1980). As each mesh size does not offer a complete geographic coverage, 333 µm is absent in the mid-Atlantic and Southern Ocean and 200 µm is absent in the equatorial and eastern Pacific, the mesh conversion equations used in O'Brien, 2005 (http://www.st.nmfs.noaa.gov/copepod/2005), were calculated using the updated mesozooplankton biomass data presented here in Table 3. As 333 µm was the most numerically abundant data type, and co-sampled 333 and 505 µm data were more prevalent than 200 and 500 µm co-sampled data, all sizes were calculated to their equivalent 333 µm values. In general, smaller mesh nets capture a larger portion of the smaller species and smaller life stages, while larger mesh nets capture less of the smaller species and life stages (Harris et al., 2000). The equations in Table 3 reduce the biomass values from 200 µm mesh nets, and increase the biomass values

ESSDD
5, 893–919, 2012

from 505 µm nets, to make them reasonably equivalent to data sampled with a 333 µm mesh net.

2.2.3 Depth intervals

Zooplankton and mesozooplankton alike are unevenly distributed with depth. Unlike the discrete depths of bottle-sampled plankton, e.g. 10 m, 25 m, over 95 % of the available mesozooplankton data in COPEPOD were sampled with a single net towed over a single depth interval that generally runs from a target depth to the surface, e.g. 0–50 m, 0–100 m, with 0–150 m and 0–200 m being the most common. Zooplankton data sampled from these depth intervals can be used to describe the average population throughout that interval, but they cannot be used to discuss data at an individual depth level, e.g. 20 m. A small handful of data were sampled at multiple depth intervals using a multiple net sampler, e.g. the Russian Juday multi-net frequently samples at depths 0–10 m, 10-25 m, 25–50 m, 50–100 m and 100–200 m. By adding these pieces together, it was possible to build standard depths, e.g. 0–25 m from 0–10 m and 10–25 m or 0–200 m from 0–10 m, 10–25 m, 25–50 m, 50–100 m and 100–200 m. The mesozooplankton biomass data presented here have been organized into 11 depth categories, which allow the data to be selected at a variety of different depths, see Table 4. Within the standard 33 level WOA data grid used in the MAREMIP database, the mesozooplankton were stored at the WOA depth level representing the mid-point of the tow interval. For example, the 0–40 m interval (zCat i040) was stored as 20 m (WOA level 2) while the 0–200 m interval (zCAT i200) was stored as 100 m (WOA level 7), see Table 4.

The data were gridded using the original entries for latitude, longitude and month from all datasets. Mesozooplankton concentrations in $\mu g\,C\,l^{-1}$ were binned on the 4-dimentional WOA grid. This is a monthly grid with horizontal resolution of 1×1 degree and 33 vertical depth levels, with the first ten levels representing depths 0, 10, 20, 30, 50, 75, 100, 125, 150, and 200 m. Depth intervals were assigned to representative WOA levels as described above. Only data that were gridded in the top 200 m of the

ESSDD
5, 893–919, 2012

ocean were used for calculation of global epipelagic mesozooplankton annual average biomass.

2.3 Quality control

Numerical range-based quality control of zooplankton data is complicated because of differences in sampling method, mesh size, seasonality and diurnal vertical migration (O'Brien, 2007). The mesozooplankton data acquired from COPEPOD already have quality control flags assigned to each value by COPEPOD. The COPEPOD quality control method (O'Brien, 2007, http://www.st.nmfs.noaa.gov/copepod/2007) for zooplankton biomass data divides the world into 15 major geographic basins, six mesh size categories, 12 months, four seasons and four biomass types.

The COPEPOD 2007 quality control system has three different types of outlier warning flags that are assigned based on three n-dependent ranging tiers. If a data value falls outside of 99 %, 99.9 % or 99.99 % of all other available same-category data present within the COPEPOD database they are flagged. Using the COPEPOD quality control system, an individual mesozooplankton wet mass collected with a 333 µm net mesh size in the North Pacific, is compared over: (1) the full numeric range of COPEPOD, e.g. all other wet mass data sampled in any oceanic region in any month (F1), (2) the basin-specific annual range, e.g. wet mass data sampled only in the North Pacific in any month (F2), (3) the seasonal range, e.g. wet mass data sampled only in that North Pacific in June, July or August (F3). For the purposes of compiling the mesozooplankton biomass data, COPEPOD mesozooplankton biomass values were excluded if their flagging indicated that they fell outside of 99.9 % of same category data from any region and any month (F1), fell outside of 99 % of same category data from the same region regardless of season (F2) and during the same season (F3).

The suggested minimum quality control for the MAREDAT datasets was to apply Chauvenet's criteria for data rejection (Glover et al., 2011; Buitenhuis et al., 2012). Chauvenet's criterion was applied only to the log-tranformed mesozooplankton biomass data, which are normally distributed. The mean $\overline{x}$ and the standard deviation

ESSDD
5, 893–919, 2012

σ of the log-transformed data were calculated and used to calculate the critical value x_c. One half of $1/(2n)$ was used because the Chauvenet's criterion is a two-tailed test, however, only data on one tail, the high side, $\overline{x} + x_c$, were rejected.

3 Results and discussions

3.1 Results of quality control

The mesozooplantkton data coming from COPEPOD had already undergone underwent rigorous in house quality control criteria (e.g. O'Brien, 2007). Out of the 156 380 originally collected mesozooplankton biomass data points, 3217 were then excluded based on COPEPOD's outlier detection flagging (quality control): 2 % of these outliers were flagged as > 99.99 % outliers, 19 % were flagged as > 99.9 % outliers and 79 % were flagged as > 99 % outliers. Chauvenet's criteria was applied to all remaining 153 163 data points of log transformed net mesh corrected carbon biomass values. No data points from the biomass dataset were rejected as outliers; all values being lower than the critical value of the mean + 4.6534 × standard deviation.

Sampling protocols, handling, preservation and measurement techniques were not considered when removing outliers. These variables are assumed reasonably consistent within COPEPOD, but are most likely not uniform across datasets and projects. Issues related to sampling such as the inherent variability of field populations (Landry et al., 2001), net mesh size, type of net, net avoidance, seasonal/diel vertical migrations, sample handling, e.g. sample splitting, size fractionation and sample analysis, all sources of random sampling error, were considered to have a greater effect then the sampling bias issues found across projects/datasets.

3.2 Biomass description

The mesozooplankton database contains 153 163 data points. Data from a number of stations that have been sampled repeatedly over many years, or programs where

ESSDD
5, 893–919, 2012

measurements have been made on a fine resolution grid have been included. Therefore, after gridding, we obtained 42 245 data points on the WOA grid ($1° \times 1° \times 12$ months $\times$ 33 depths), representing coverage of annually averaged biomass for 20 % of the ocean surface. To limit the overrepresentation of well-sampled locations, we present results of the gridded data.

The gridded data was split between regions as follows: 46 % of the data were found in the Pacific Ocean, 16 % in the Atlantic Oceans, 16 % in the Indian Ocean and 14 % in the polar oceans. The tropics, including the Equatorial Atlantic, Equatorial Pacific, Indian Ocean, which represent 43 % of the ocean surface, accounted for 39 % of the data. In contrast 14 % of the data came from the polar oceans, which represent 5 % of the ocean surface. Only 22 % of the data were found in the Southern Hemisphere (Fig. 4). There is some sampling bias towards the local summer season (Fig. 5e and f), with peak cells found in summer months in both hemispheres.

The distribution of biomass values between open water and shelf water was also examined. "Shelf water" was defined as a 1-degree grid cell in an area with a bottom depth of less than 200 m or adjacent to a grid containing land. Globally, the ratio of open vs. shelf water values were exactly 50 %. However, when Northern and Southern Hemispheres are compared, the partitioning between open and shelf water was 47 % to 53 % in the north and 80 % to 20 % in the south, i.e. the Southern Hemisphere data were dominated by open water values. These values reflect the asymmetry in the proportion of samples collected in both hemispheres. Greater shelf water area and greater sampling effort (in terms of samples collected) in the Northern Hemisphere is important to consider when comparing these values. Although open water values seem to dominate the Southern Hemisphere data biomass values for the region may not necessarily reflect de facto open water environment. Ice cover in the Southern Ocean means that although many samples are collected along the ice edge, the effective coastline, depending upon the season, these are labeled as "open" water by the criteria stated above.

ESSDD
5, 893–919, 2012

3.3 Global estimates

Global mesozooplankton biomass had a mean of 5.9 µg C l^{-1}, a median of 2.7 µg C l^{-1} and a standard deviation of 10.6 µg C l^{-1}. Biomass was highest in the Northern Hemisphere, in the North Atlantic, North Pacific, and Arctic, but the general trend was a slight decrease from polar oceans to temperate regions with values increasing again in the tropics (Table 5). The standard deviation within the latitude bands was high so the differences in the mean were not significant. The global annual average of mesozooplankton biomass, sampled to a depth of 200 m and based on the median biomass concentration value (2.7 µg C l^{-1}), was estimated at 0.19 Pg C.

4 Conclusions and recommendations

A coherent global map of mesozooplankton global distribution and biomass is presented. Global mesozooplankton biomass was estimated from the median biomass value of 2.7 µg C l^{-1} (= 0.19 Pg C annual average mesozooplankton biomass in the top 200 m) and a standard deviation of 10.6 µg C l^{-1}. The global, latitudinal and depth estimates of biomass concentrations will be useful for understanding ocean biogeochemistry, and for evaluating global models that include mesozooplankton. Although less developed versions of the mesozooplankton data have been published before as part of the regular COPEPOD database report series (O'Brien, 2005, 2007, 2010), this is the first time individual mesh categorized (mCAT) and depth intervals (zCAT) have been distributed. This is also the first time these data have been collected together as a whole for publication in a journal together with the publication of the associated dataset. The dataset description and methods should act as a guide to those interested in using this dataset. It is important when using a dataset such as this that the associated caveats are understood and considered when drawing conclusions based on this data.

ESSDD
5, 893–919, 2012

Communication between biogeochemical modelers, data managers and experimentalists is at an all time high. There is an increasing interest to combine expertise from the modeling and experimentalist communities to produce and share the data products necessary to parameterize and validate marine ecosystem models. COPEPOD regularly interacts with scientific projects such as MAREMIP and international working groups such as the ICES Working Group on Zooplankton Ecology (WGZE). Through collaboration with the scientists and user community, COPEPOD strives to constantly improve its data content and to ensure data products, such as the biomass fields in this paper, are available and useful to the scientific community.

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ESSDD

5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

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ESSDD
5, 893–919, 2012

Table 1. Sources for COPEPOD mesozooplankton biomass and biovolume data.

Dataset Title (as used in data files)	# of Mcells	*Mcell Ranking*	% Contribution to Global Field	Cumulative % Contribution	# of Observations	*Observation Ranking*	Abbreviated Information
CalCOFI	1952	**1**	7.5 %	7.5 %	38 548	***1***	California Cooperative Oceanic Fisheries Investigations (CalCOFI)
Odate Collection	1695	**2**	6.5 %	14.1 %	16 395	***3***	Dataset of Zooplankton Biomass in the Western North Pacific Ocean (1951–1990, K. Odate Collection).
IIOE	1409	**3**	5.4 %	19.5 %	1826	***15***	International Indian Ocean Expedition (IIOE)
HUFO-DAT	1347	**4**	5.2 %	24.7 %	3783	***7***	Hokkaido University Long-term Fisheries and Oceanographic Database (HUFO-DAT)
EASTROPAC	1287	**5**	5.0 %	29.7 %	3497	***8***	Eastern Tropical Pacific (EASTROPAC: 1967–1968) project
CSK	1207	**6**	4.7 %	34.3 %	2462	***9***	Cooperative Study of the Kuroshio and adjacent regions (CSK)
NMFS Marine Mammal Surveys	871	**7**	3.4 %	37.7 %	977	***23***	NMFS Southwest Fisheries Science Center (SWFSC) Marine Mammal surveys
IBSS Biomass Collection	825	**8**	3.2 %	40.9 %	1324	***21***	Institute of Biology of the Southern Seas (IBSS)
EcoFOCI	785	**9**	3.0 %	43.9 %	8803	*5*	Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI)
INODC Zooplankton	715	**10**	2.8 %	46.6 %	1851	***14***	National Institute of Oceanography (NIO) zooplankton database.
SEAMAP	704	**11**	2.7 %	49.4 %	9019	***4***	Southeast Monitoring and Assessment Program (SEAMAP)
Vityaz Pacific Ocean and Indian Ocean Cruises	594	**12**	2.3 %	51.7 %	1971	***13***	Institute of Oceanology/USSR Academy of Sciences – Vityaz Data Archive
EcoMon-RV (continuation of *MARMAP*)	593	**13**	2.3 %	53.9 %	18 749	***2***	NMFS Northeast Fisheries Science Center (NEFSC) Ecosystem Monitoring (EcoMon) Research Vessels division (EcoMon-RV)
VITYAZ Zooplankton	580	**14**	2.2 %	56.2 %	3948	***6***	Institute of Oceanology/USSR Academy of Sciences – Vityaz Data Archive
North Pacific Survey	518	**15**	2.0 %	58.2 %	944	***25***	North Pacific Survey 1955–1958
Institute of Marine Research – JAKARTA	503	**16**	1.9 %	60.1 %	1327	***20***	Institute of Marine Research – Jakarta, National Institute of Oceanology, Indonesian Institute of Sciences
BCF – POFI	494	**17**	1.9 %	62.0 %	1155	***22***	Bureau of Commercial Fisheries (BCF) – Pacific Oceanic Fisheries Investigations
PINRO Collection	491	**18**	1.9 %	63.9 %	2432	***10***	Knipovich Polar Research Institute of Marine Fisheries & Oceanography (PINRO)
CSIRO Australia	476	**19**	1.8 %	65.8 %	1496	***17***	Commonwealth Scientific and Industrial Research Organization (CSIRO)
R/V *ELTANIN*	463	**20**	1.8 %	67.5 %	972	***24***	United States Antarctic Research Project (USAP/USARP)
JMA North Pacific Surveys	461	**21**	1.8 %	69.3 %	1806	***16***	Japan Meteorological Agency (JMA)
NORWESTLANT	444	**22**	1.7 %	71.0 %	835	***27***	International Commission for the Northwest Atlantic Fisheries (ICNAF) – Northwest Atlantic project
EQUALANT	369	**23**	1.4 %	72.5 %	737	***28***	Equatorial Atlantic Surveys (EQUALANT) I, II, III
JARE	359	**24**	1.4 %	73.8 %	712	***29***	Japanese Antarctic Research Expedition (JARE) database – National Institute of Polar Research (NIPR)

ESSDD
5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

Table 1. Continued.

Dataset Title (as used in data files)	# of Mcells	*Mcell Ranking*	% Contribution to Global Field	Cumulative % Contribution	# of Observations	*Observation Ranking*	Abbreviated Information
NMFS-SWFSC Surveys	347	**25**	1.3 %	75.2 %	2050	***11***	NMFS Southwest Fisheries Science Center (SWFSC) near shore surveys
Foxton 1956	341	**26**	1.3 %	76.5 %	1354	***19***	P. Foxton Discovery Reports Volume XXVIII (1956)
IMR Norwegian Sea Survey	337	**27**	1.3 %	77.8 %	878	***26***	Institute of Marine Research (IMR)
EASTROPIC	264	**28**	1.0 %	78.8 %	551	***30***	Eastern Tropical Pacific project (EASTROPIC: 1955)
IMECOCAL	233	**29**	0.9 %	79.7 %	2048	***12***	Investigaciones Mexicanas de la Corriente del California (IMECOCAL)
R/V *Dolphin Cruise*	226	**30**	0.9 %	80.6 %	1463	***18***	R/V *Dolphin* cruises (1965–1968)
Sum of the 30 Data Sets listed above	**20 890**		**80.6 %**	**79.7 %**	**133 913**		** Data sets 31 through 110 individually contributed Mcells of less than 1 % each to the global biomass fields, but contributed 19.4 %
80 Additional Data Sets (**)	**5033**	*31–110*	**19.4 %**	**21.2 %**	**22 761**	*31–110*	of the total Mcells and 21.2 % of the total records with all eight sets combined together.
Grand Total	**25 923**	**Mcells**			**153 163**	**records**	

ESSDD

5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

Table 2. Biomass conversion equations.

Original Biomass Measure	Equation	Reference
Displacement Volume (DV) to Carbon Mass (CM)	$\log CM = (\log DV + 1.434)/0.820$	Wiebe (1988)
Wet Mass (WM) to Carbon Mass	$\log CM = (\log WM + 1.537)/0.852$	Wiebe (1988)
Dry Mass (DM) to Carbon Mass	$\log CM = (\log DM - 0.499)/0.991$	Wiebe (1988)
Settled Volume (SV) to Dry Mass	$\log DM = 0.843 \cdot \log SV + 1.417$	Balvay (1987)
Dry Mass to Carbon Mass	$\log CM = (\log DM - 0.499)/0.991$	Wiebe (1988)
Ashfree Dry Mass (AFDM) to Carbon Mass	$\log CM = (\log AFDM - 0.410)/0.963$	Bode et al. (1998)

ESSDD
5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

Table 3. Net mesh conversion equations.

Original Mesh Size	Equation	Reference
Mesozooplankton carbon mass sampled via 200 µm mesh net (CM_{M200}) to 333 µm mesh equivalent (CM_{M333})	$\text{Log } CM_{M333} = 0.6195 \cdot \log CM_{M200}$	O'Brien (2005)
Mesozooplankton carbon mass sampled via 505 µm mesh net (CM_{M505}) to 333 µm mesh equivalent (CM_{M333})	$\text{Log } CM_{M333} = 1.2107 \cdot \log CM_{M505}$	O'Brien (2005)

ESSDD
5, 893–919, 2012

Table 4. Description of COPEPOD depth interval criteria and World Ocean Atlas equivalents.

COPEPOD zCAT	Upper	Lower	Max upper	Min lower	Max lower	Min zdiff*	World Ocean Atlas	
	z-target (m)		z-allowed				z-ID	z-LAYER
i010	0	10	3	–	15	8	1	0
i020	0	20	5	15	30	16	2	10
i040	0	40	5	30	50	32	3	20
i060	0	60	10	50	80	48	4	30
i100	0	100	10	80	125	80	5	50
i150	0	150	10	125	175	120	6	75
i200	0	200	15	175	225	160	7	100
i250	0	250	15	225	275	200	8	125
i300	0	300	15	275	350	240	9	150
i400	0	400	20	350	450	320	10	200
i500	0	500	20	450	600	400	11	250

Notes:
(80 % of interval)
COPEPOD zCAT is the COPEPOD four character token used to represent each depth interval, e.g. i010 = 0–10 m, i100 = 0–100 m, i200 = 0–200 m. **Upper z-**and **Lower z-Target** are the ideal depth intervals desired by this (zCAT) category. **Max upper** *z* is the maximum non-surface interval allowed by this zCAT. (This really applies more to deeper depth intervals and multi-net tows, i.e. 0–25 m, 25–50 m). **Min** and **Max lower** *z* **allowed** are the allowed range above and below the lower z-target. (They keep the individual COPEPOD zCAT's from overlapping with each other). **Min zdiff allowed** is important if a tow is shorter than (found within) the min and max depths, this makes sure it has at least an 80 % coverage of the interval. (This is to prevent a "0–500 m" tow from being comprised of a 400–500 m – only net fragment).
Supplementary note:
In any given tow interval within the COPEPOD dataset, a Bottom Depth Correctin Flag (BDCF) will be set if the bottom depth at the sampling location is less than the lower target range for a given zCAT. This means that a 0–100 m tow in a 110 m bottom depth area would qualify as a i100, i150, i200, i250, i300, i400, and i500 value. Except for the i100, the other depths would include a "BDCF" marked in the data file. This allows a user to use all data from a single depth category, i.e. i200, or to combine multiple depth categories, i100, i150, i200 – by excluding any BDCF flags to remove duplicated data between the multiple depth files.

ESSDD
5, 893–919, 2012

Table 5. Global and latitudinal band values for the gridded mesozooplankton biomass data.

	Biomass (µg C l^{-1})					
Latitude	*n*	Min.	Max.	Mean	Median	±std.
Global	42245	0.017	345.4	5.91	2.68	10.57
90–40° N	13539	0.019	302.6	7.76	3.61	11.59
40–15° N	14247	0.017	345.4	6.34	2.81	11.43
15° N–15° S	8825	0.057	240.5	4.63	2.67	9.33
15–40° S	2230	0.029	44.93	1.66	0.98	2.35
40–90° S	3404	0.020	177.3	2.91	1.48	5.93

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ESSDD

5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

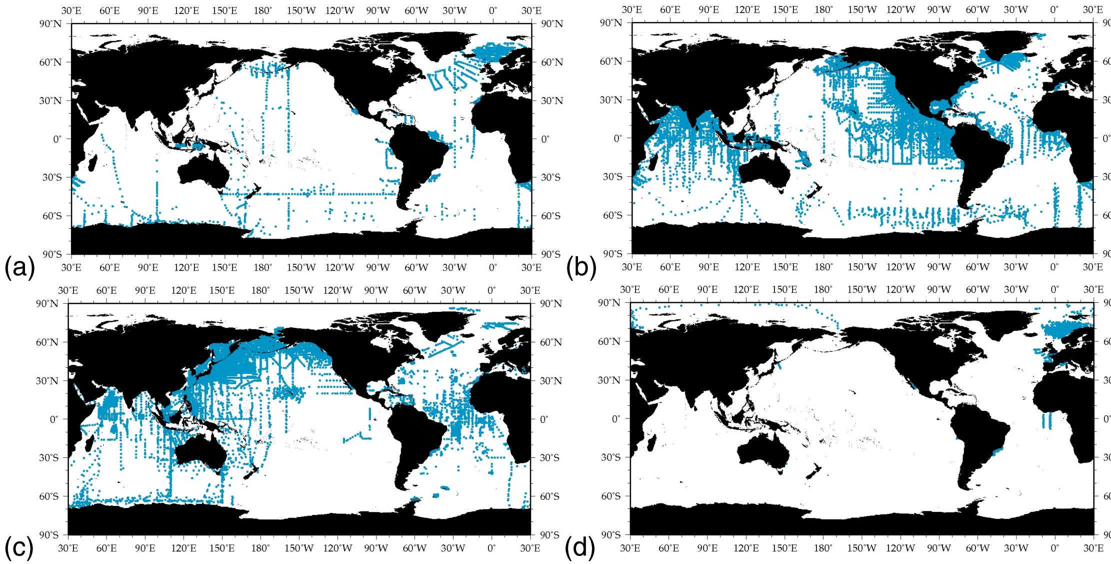

Fig. 1. Distribution of the different types of biovolume and biomass samples: **(a)** settled volume, **(b)** displacement volume, **(c)** wet mass and **(d)** dry mass.

ESSDD
5, 893–919, 2012

Mesozooplankton biomass in the global ocean

R. Moriarty and T. D. O'Brien

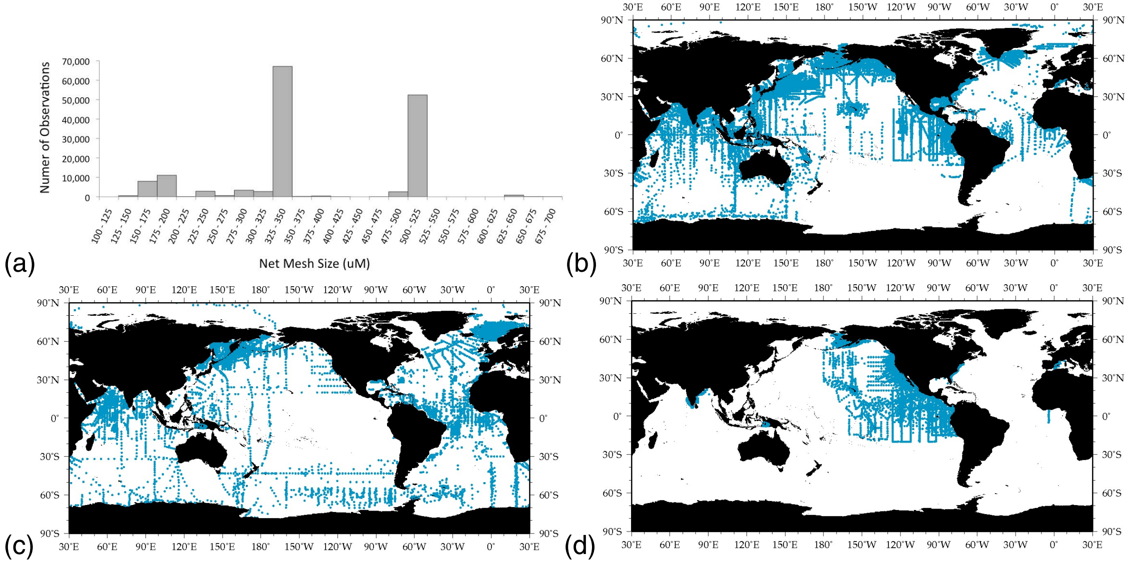

Fig. 2. Biomass and biovolume net mesh distribution: **(a)** frequency distribution of net mesh size (µm), **(b)** distribution of 333 µm, **(c)** 200µm and **(d)** 505 µm net mesh catches.

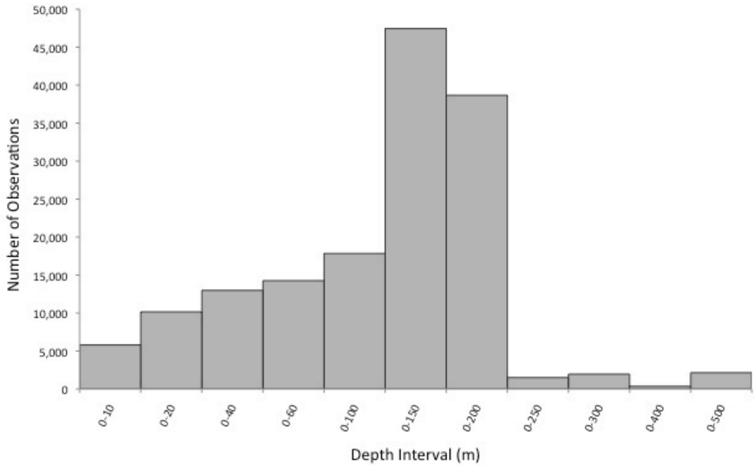

Fig. 3. Distribution of sampling depth original sampling depth. Depth 0–10 corresponds to i010, depth 0–20 to i020, etc. (see Table 4).

ESSDD
5, 893–919, 2012

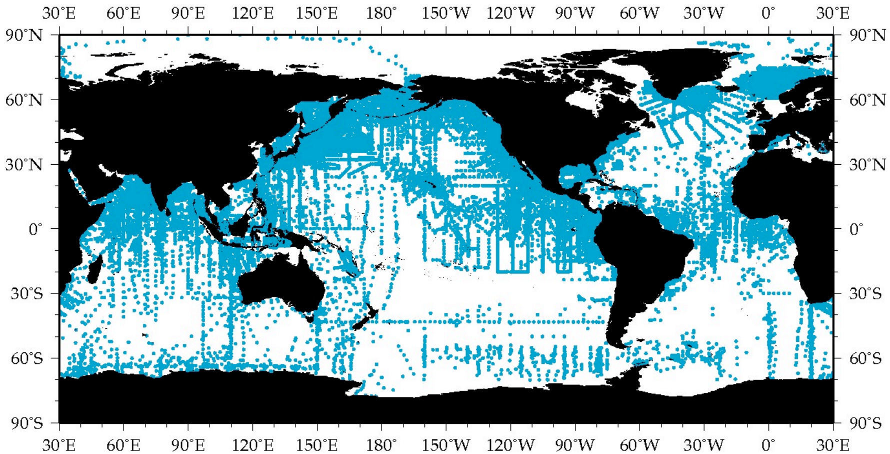

Fig. 4. Global distribution of all mesozooplankton biomass data (converted to carbon and a common 333 µm equivalent mesh size). Each point represents a station where mesozooplankton were recorded.

ESSDD
5, 893–919, 2012

R. Moriarty and T. D. O'Brien

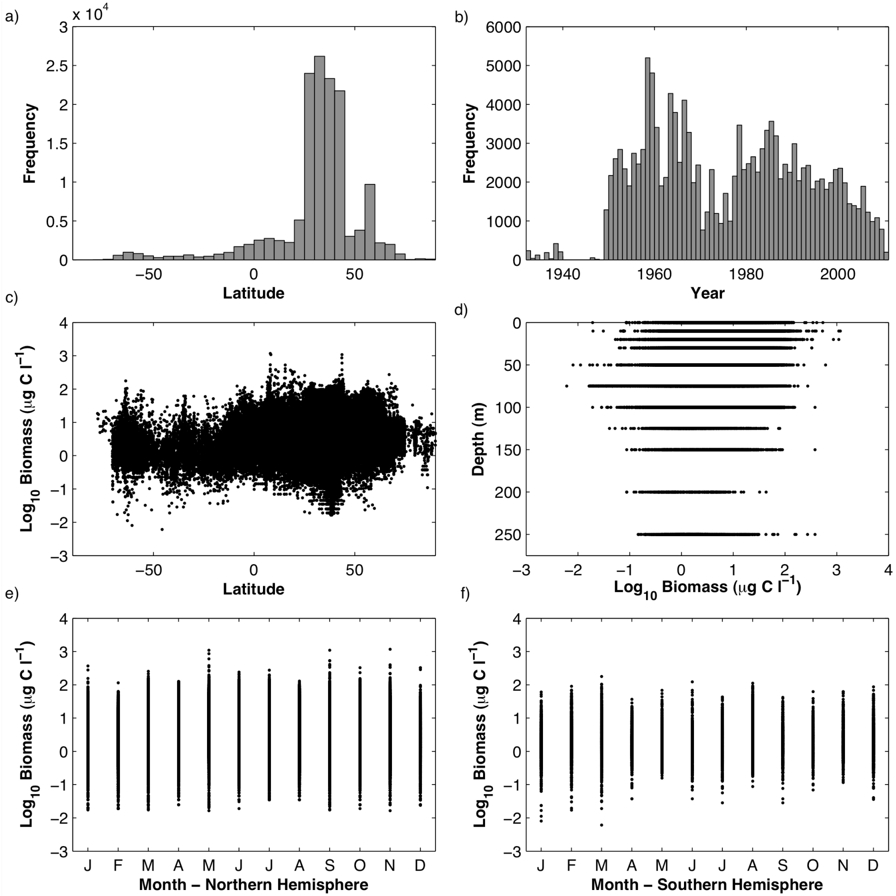

Fig. 5. Description of mesozooplankton biomass observations: **(a)** latitudinal distribution, **(b)** yearly distribution, **(c)** latitudinal depth distribution, **(d)** depth distribution, **(e)** monthly distribution in the Northern and **(f)** Southern Hemispheres.

ESSDD

5, 893–919, 2012

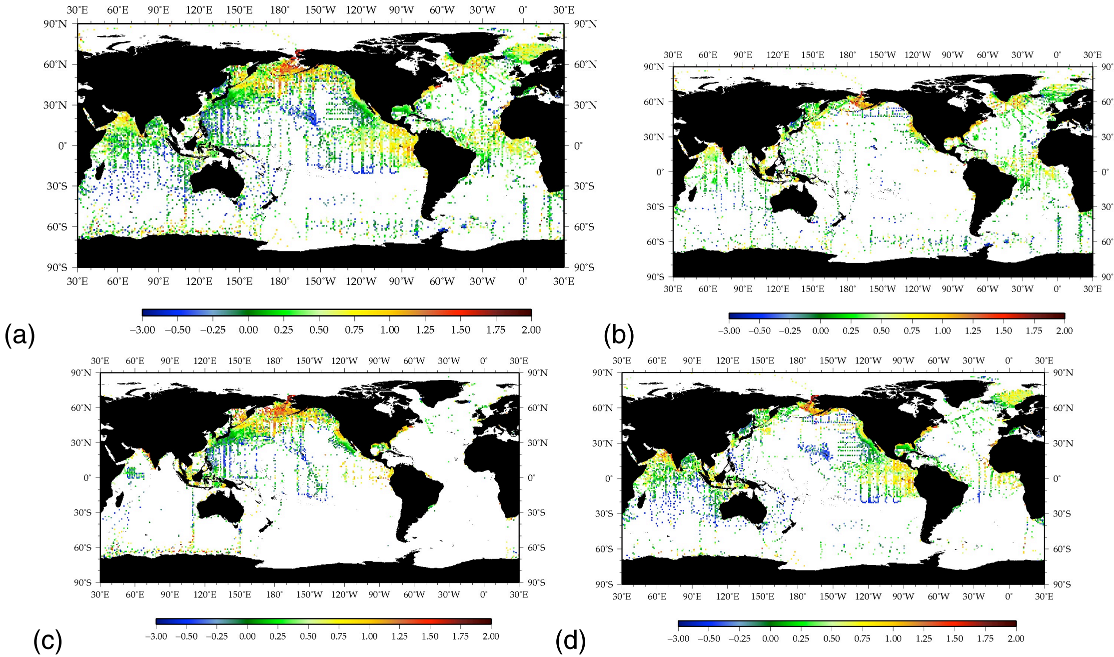

Fig. 6. Annual mean mesozooplankton biomass (µg C l^{-1}): **(a)** sampling depth interval: 0 to 200 m, combined depths i100, i150, i200, **(b)** sampling depth interval: 0 to 100 m, combined depths i100, **(c)** sampling depth interval: 0 to 150 m, combined depth i150 and **(d)** sampling depth interval: 0 to 200 m, combined depth i200. Sample net mesh of ∼ 333 µm in all.

ESSDD
5, 893–919, 2012