Data on zooplankton occurrence and abundance in the Far East seas and adjacent Pacific Ocean waters

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Abstract. The article describes a unique dataset of zooplankton collected by the large Juday net in the North Pacific – one of the most productive and economically important regions of the world ocean (Volvenko, 2021a https://doi.pangaea.de/10.1594/PANGAEA.937751): the sources and extent of the information contained therein, its benefits and drawbacks, the first operating experience and prospects. The information in this dataset has already been used to quantify

10   the inventory of marine biological resources and appraise the waters of the Far East seas and adjacent Pacific Ocean. In 2016, five tabular reference books were created and printed containing the species composition, occurrence (samples, %) and abundance (ind./m^3, mg/m^3) of zooplankton in the surveyed area. The data is aggregated by species, developmental stages, size fractions, standard regions, vertical layers of water, light and dark time of day, four seasons of the year and multi-year periods. This information has recently been verified, corrected, translated into English and from text to digital format, and

15   supplemented by GIS with maps of the standard regions by which data was summarized with their morphometric characteristics (Volvenko, 2021b https://doi.pangaea.de/10.1594/PANGAEA.937752) to increase its availability to the scientific community worldwide. The scope of application of this data is fundamental to the management of marine resources, aquaculture development, nature conservation, and assessment of the damage of various anthropogenic factors on nature.

Keywords: assessment of waters; database; long-term monitoring; North Pacific; tabular reference books; zooplankton

1 Introduction

20   Since the end of the 1970s the Pacific Branch of Russian Federal Research Institute of Fisheries and Oceanography (TINRO) has adhered to the ecosystem approach to the study and management of living aquatic resources, which involves the collation and analysis of data for all groups of animals, highlights the interconnections between them and the role of the climate and hydrological regime in the fluctuations of their numbers (May, 1984; Shuntov, 1988, 1995, 2004, 2010; Shuntov et al., 1997;

25   Lapko, 2000; Bocharov, Shuntov, 2003; Dulepova, 2005; Misund, Skjoldal, 2005; Bianchi, Skjoldan, 2008; Beamish, Rothschild, 2009; Bulatov, Kotyenyov, 2012; Shuntov, Temnykh, 2013). In large-scale integrated marine expeditions, all sorts of information about marine biological communities and their abiotic environment have been collated via this approach over the last 45 years in the North Pacific and adjacent Arctic. Nekton, benthos and nektobenthos are counted primarily by the

trawling method, and each trawl is accompanied by the collation of oceanographic data. Since 1984 up to now, plankton
30   samples have been taken at all measurement stations according to a common standard.

Mesofauna, the details of which are aggregated in the new dataset described here, is caught by the plankton net. These
organisms have a small body size and weight from hundreds to thousandths of a milligram, and are primarily the food supply
for trawl macrofauna, marine birds and mammals, and also the larvae of invertebrates and fish, the so-called *net zooplankton*[1].

This dataset contains information on the status and spatial-temporal dynamics of the planktonic part of the highly
35   productive ecosystems (which provides 90% of the total Russian catch of fish and other marine organisms (Bocharov, 2004,
2010) during a time period in which there were considerable transformations in the biota of the region caused by changes to
global climate and oceanological and cosmic-geophysical factors (e.g.: Shuntov et al., 1993, 1997, 2007; Shuntov, 1994, 1998;
Shuntov, Temnykh, 2011). Therefore, it is difficult to overestimate its role in the ecosystem, biogeographic, trophological and
bioresource studies of the Far Eastern seas of Russia and adjacent waters of the Pacific Ocean.

40   The article provides a detailed description of how this unique dataset was created, the sources and volume of information
contained in it, its benefits and drawbacks, some results achieved through it concerning the quantitative inventory of marine
biological resources and appraisal of waters in the North Pacific, the future prospects for its utilization in applied and
fundamental research

2 Materials and Methods

45   Plankton were collected using a large standard sized Juday net made of kapron sieve No. 49 (0.168 mm mesh) with a 0.1 m2
opening (Fig. 1) from a depth of 200 m to the surface, and where the depth is less than 200 m from the bottom to the surface.
To study the upper pelagic water layer additional plankton samples were collected in the standard layer 0-50 m. Other depths
are sampled layer-by-layer to study the migration and of vertical distribution plankton. Samples processed by the express
method (Volkov, 1984, 1996a, 2008a) with the separate analysis of three size fractions – length of 0.6-1.2 mm (fine/small),
50   1.2-3.2 mm (medium) and > 3.2 mm (large). Research groups usually work in two shifts, so the data collection takes place
both day and night in order to calculate the vertical diurnal migration of euphausiids, copepods and hyperiids, which descend
during the day into the deeper layers beyond the epipelagic zone. Surveys are performed all year round, if possible, and
annually across standard sampling grid. They regularly cover the entire exclusive economic zone of Russia and sometimes the
adjacent waters (Volvenko, 2015a).

55   Other features of the collection, processing and storage of data are described in Supplement 1.

3 Results

During the implementation of the Concept of Information Support for fundamental and applied research (Volvenko, 2015a,
2016) a zooplankton DB was created (see Supplement 1 for details). Based on the DB, in 2015 five tabular reference books

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[1] Hereinafter referred to as zooplankton for short without specifying that it is net zooplankton and without the prefix meso.

(Dolganova, Volvenko, 2016a, b; Volkov, Volvenko, 2016a-c) of the species composition and abundance of zooplankton in a major fishing region of Russia (Fig. S3) were prepared and submitted for publication. Three of them are devoted to the Far Eastern seas: the western part of the Bering Sea, the north-west of the Sea of Japan and the Sea of Okhotsk; one – the northwestern part of the Pacific Ocean. The increased density of the measurements is clearly visible in these areas (Fig. 1), as they were taken in an area, which is constantly monitored by the TINRO, and studied much better than others. A separate volume is devoted to the Peter the Great Bay in the Sea of Japan. This bay has unique fauna, its coast contains much of the populace and industry of the Russian Far East, it has a highly promising aquaculture industry, and unlike most other areas of the Far Eastern seas, only the plankton in the neritic zone has been adequately studied here. The new tabular reference books contain a total of nearly five thousand pages.

The tables contain information on the occurrence (number of samples in which this species/group of animals was found, and their share in percentage terms of the total number of measurements), the average abundance (specimens /m^3 and mg/m^3) and the standard error of mean with the Sheppard's correction. The species and other taxonomic groups of marine organisms are not sorted systematically but in alphabetical order, and then in ascending order of size by fraction, developmental stage and/or size. The final rows of the tables – "Entire zooplankton", "Meroplankton", "Amphipods", "Copepods", "Euphausiids" etc. (see left column in Table S3) contain the corresponding total group means and standard errors calculated by the formula

$$m_{\sum_x} = \sqrt{m_1^2 + m_2^2 + ... + m_n^2}$$, where $m_{\sum^x}$ is the sampling error of the sum n of the arithmetic means, following their errors $m_1 - m_n$.

Examples of five tables from (Volkov, Volvenko, 2016a) are given in the Supplement 2 to this article. They contain long-term average data about the plankton of regions No 1-5 (see Fig. 1) of the Bering Sea.

In general the format of these tables is the same as in the previously published reference books on nekton published in 2003-2006 (Shuntov, Bocharov, 2003b, 2004b, 2005b, 2006b) as tabular annexes to nekton atlases (Shuntov, Bocharov, 2003a, 2004a, 2005a, 2006a), tabular reference books on the pelagic trawl macrofauna published in 2012 (Shuntov, Bocharov, 2012a-c), and benthic macrofauna published in 2014 (Shuntov, Bocharov, 2014a-e). Information in them is also grouped by: 56 standard biostatistical areas (see 48 light unshaded areas on the bottom map Fig. 1, and 8 areas in the insert in its middle left corner), which are natural systems characterized by relatively uniform waters according to the formation of their properties in specific local geographical, geomorphological, climatic and hydrological conditions. There is now a certain standard for geo-referencing spatially distributed information, ensuring the comparability of diverse environmental information and the continuity of the long-term monitoring data on the state of the waters (Volvenko, 2003d).

Besides the described zoning, the reference books contain four principles relating to grouping and the selection of raw data:

1) By sampled water layer, measurements are divided into:

epipelagic – final catch depth 0 m, initial 100-200 m (or the bottom, if depth is ≤ 300m),

upper epipelagic – final catch depth 0 m, initial 25-50 m (or bottom, if depth is ≤ 70 m).

2) By time of day they are divided into:

day – obtained during daylight,

night – obtained in the dark or at dusk.

95   3) Seasonally (in this case, this means not the calendar but the biological seasons, the measurements are divided into made:

from June 1 to September 15 – *summer*,

from September 16 to November 30 – *autumn*,

from December 1 to March 31 – *winter*,

from 1 April to 31 May – *spring*.

100   4) There are 4 multi-year periods:

1984-1990 – 'Sardine and pollock fish abundance',

1991-1995 – 'Transitional period of sharp decline in abundance',

1996-2005 – 'Period of low-level new fish productivity growth',

2006-2013 – 'Salmon period'.

105   These principles of grouping, selection and averaging data are implemented in the majority of the TINRO ecological studies (e.g.: Shuntov, Bocharov, 2003a-b, 2004a-b, 2005a-b, 2006a-b, 2012a-c, 2014a-e; Volvenko, 2003a-c, 2004a-c, 2005a, b, 2007, 2016; Shuntov et al., 2007; Shuntov, Temnykh, 2008; Volkov, 2014 and many others).

4 Discussion

The data in these tables enable evaluation of the total stock plankton biological resources of the Far Eastern seas of the North

110   Pacific. With the use of the so-called volume method, the absolute abundance of marine organisms is calculated by multiplying their average density (specimens/m^3 or mg/m^3) by the corresponding volume of water (thousand km^3). The result gives, respectively, trillions of specimens and thousands of tons. For this, the standard morphometric characteristics of the areas listed in each of the aforementioned tabular reference books should be used. For convenience, they are all placed in dbf files of maps in Volvenko (2021b). (Note that many opponents of applying corrections to catch efficiency can easily recalculate the data

115   published in books in their own way, by divide any of the density parameters – abundance or biomass – by the correction factor given in each row. Those who wish to use different correction factors can also easily recalculate the density by dividing it by our correction and then multiplying it by their own).

      With these same tables it is easy to recalculate the volumetric characteristics of density into areal characteristics. To do this, multiply the average abundance or biomass by volume of water corresponding to the water area, and then divide it by its

120   area. The result will be in the billions of specimens/km^2 or t/km^2. From the tables it is easy to calculate the plankton content in the middle and lower epipelagic, i.e. from 50-200 m (based on the difference of concentrations from 0-200 m and 0-50 m) and the average individual weight of animals (by dividing their biomass by number), and using previously published tables on calorific value and the chemical composition of zooplankton (e.g. Borisov et al., 2004), you can obtain its energy

characteristics, etc.

125  In this way a significant contribution to the new quantitative inventory of aquatic biological resources and appraisal of the waters of the North Pacific has been made. A series of these monographs is recommended not only to planktonologists, but also to ecologists, biogeographers, hydrobiologists, ichthyologists, teachers and students of related disciplines. In the scope of their application is the management of living aquatic resources, aquaculture development, and nature conservation, because they can be used to assess the effects of various anthropogenic factors on nature (pollution, the construction of hydraulic
130 structures, oil and gas extractions, tanker accidents, nuclear reactors, etc.)[2].

  The free wide international use of the data published in the five reference books has so far been hampered by three circumstances. 1) They are published in Russian and not translated into English. 2) They are published in text (pdf) format and not digitized. 3) The data collectors used outdated species identification guides, so there are many outdated species names in the tables (Table S4).

135  To eliminate these shortcomings, I:

- wrote this article detailing the origin of the data and methods of its processing;
- digitized the data of reference tables from five books (Fig. S3) and saved them in xlsx and csv formats;
- translated the Russian text into English;
- fixed species names to modern;
140 • summed up the characteristics of abundance where synonyms were considered as different species;
- prepared a shape-file with polygons of the standard regions (Fig. 1) by which data is summarized;
- accompanied the polygons with information about coordinates, surface areas and water volumes in each of them.

5 Data availability

Full dataset provided in xlsx and csv files (Volvenko, 2021a https://doi.pangaea.de/10.1594/PANGAEA.937751) as well as
145 maps of regions with their morphometric characteristics in shapefiles (Volvenko, 2021b https://doi.pangaea.de/10.1594/PANGAEA.937752). For purchase hard copy of reference books (their electronic versions are freely available now at the links in the list of references) one should contact the Directorate of the Pacific Branch of Russian Federal Research Institute of Fisheries and Oceanography (TINRO) E-mail: tinro@tinro-center.ru, contact information on the site: http://www.tinro.vniro.ru/en/contacs; or Directorate of the Russian Federal Research Institute of Fisheries and
150 Oceanography (VNIRO) E-mail: vniro@vniro.ru, contact information on the site: http://vniro.ru/en/about-vniro/contacts

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[2] However, in the process of testing the DBs, when creating the tabular reference books some irremovable shortcomings were found (see Supplement 1). This is common to most modern zooplankton datasets.

6 Conclusions

According to the reputable expert opinions, the dataset described above is stronger than many of the widely spatially covered zooplankton datasets available. Despite the shortcomings noted in Supplement 1, the substantial volume and high quality of the collated data gives hope that the information presented in the five reference books and these dataset together with previously

155   published data on pelagic and benthic macrofauna and data on the nutrition of common fish and squid, which is now being compiled in the TINRO laboratories, will enable the next important steps to be taken in the understanding of the nature of the Far Eastern seas and the Pacific.

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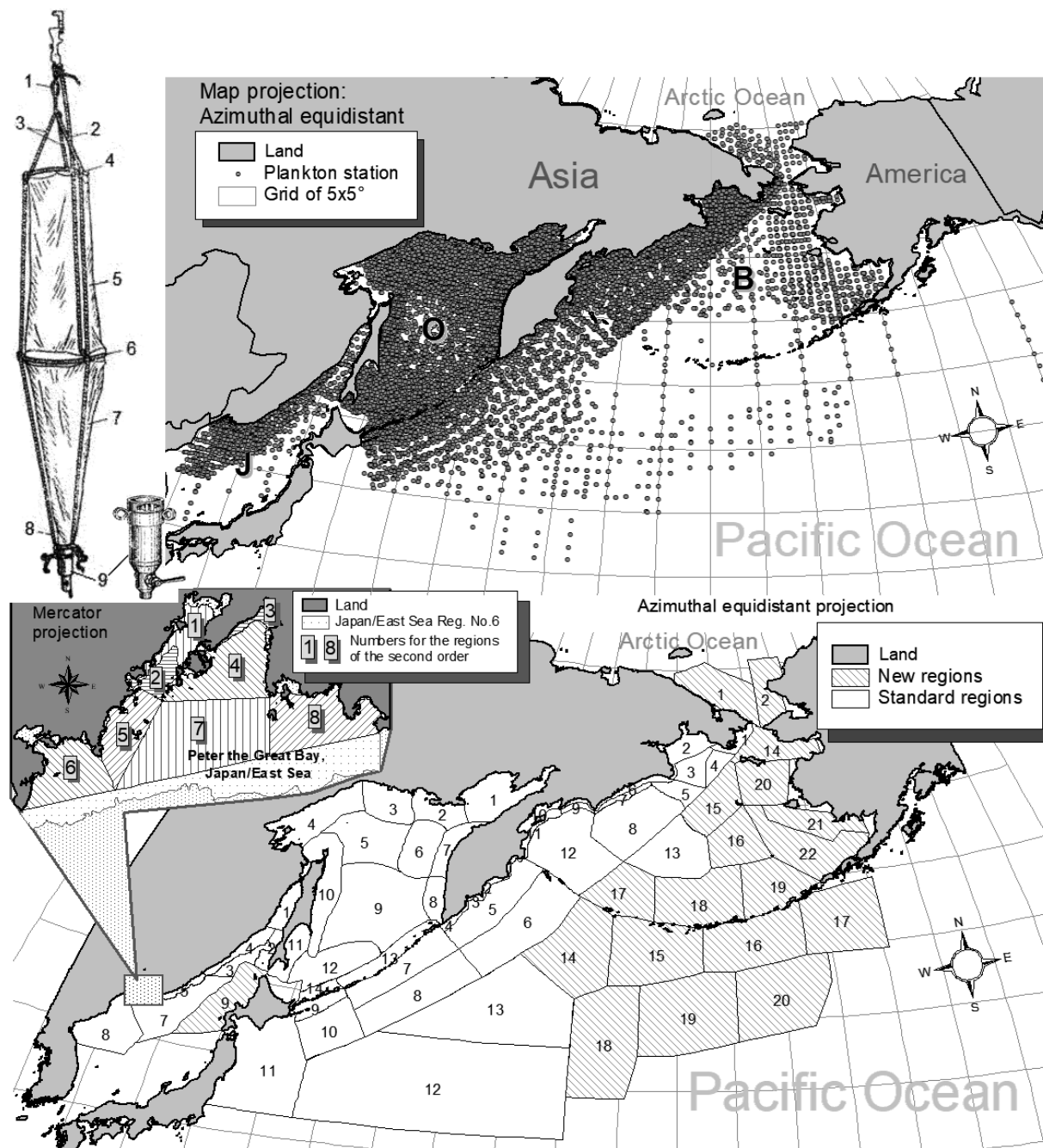
Figure 1: The upper left corner shows Large Juday plankton net: 1 – cord loop, 2 – cord that connects the net to the closing device, 3 – cords on the upper ring, 4 – upper ring, 5 – cloth cone, 6 – lower ring, 7 – silk net, 8 – cord that holds the tub, 9 – tub. The top map shows spatial distribution across the surveyed waters of 25,512 plankton measurement stations (235 surveys), from which the data obtained, has been entered into the database. Abbreviations: B – Bering Sea, O – Sea of Okhotsk, J – Sea of Japan (East Sea). The bottom map shows standard regions in which averaging of biostatistical information in the waters of permanent (light) and periodic (shaded) monitoring is performed. In the middle left tab – secondary regions, which the 6th region of the Sea of Japan is divided into.