Inter-annual and latitudinal changes in zooplankton abundance, biomass and size composition along 180° transect in the North Pacific during summers: analyses with an Optical Plankton Counter

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Microscopic analysis:
Required taxonomic skill and time consuming

**Optical Plankton Counter (OPC):**
Accurate size and number of zooplankton quantified shortly

**Normalized Biomass Size Spectrum (NBSS):**
Index of structure of marine ecosystem

**Object**
To evaluate latitudinal and annual changes in zooplankton size stricture and NBSS along 180° in the central North Pacific
Materials and methods

Location: 35°N-51°N along 180°
(n=351, 12-31 in each year)
Sampling: Vertical tow of NORPAC net (335 m mesh) from 150 m
Hydrography: Temperature and salinity were measured with CTD

Region (3) Regime (3)
Methods (OPC measurement)

Size and number of zooplankton measured shortly (ca. 15 minutes per sample)

Biomass estimation
Wet mass (WM) of zooplankton estimated from ESD assuming density of zooplankton as equal to water

\[ WM = \frac{1}{6} \pi \cdot \pi \cdot \pi \cdot ESD^3 \]

WM was converted to dry mass (DM) assuming water content as 90% 

\[ DM = WM \cdot 0.1 \]
Method (NBSS: Normalized Biomass Size Spectra)

Slope and intercept of NBSS are indices of ecosystem structure

X-axis: Log biomass (g ind.\(^{-1}\))

Y-axis: Log normalized biomass ([g DM m\(^{-3}\) weight [g DM]])

NBSS: \(Y = aX + b\)
\((a = \text{slope}, \ b = \text{intercept})\)

Data analysis

Latitudinal and annual changes in hydrography, zooplankton abundance, biomass and NBSS were tested by one-way ANOVA and Fisher’s PLSD
Results: OPC calibration

\[ Y = 1.176 \times X \]

\[ r^2 = 0.521 \]

OPC slightly higher than measured values (1.176 times)

This factor is well corresponded with the reported values from North Pacific (0.96-1.16 times)

Biomass conversion \((X/1.176)\) was made for OPC-derived mass

Normal samples

Dominated by gelatinous zooplankton

Dominated by phytoplankton
Results: Latitudinal and annual changes in hydrography

**Temperature**
- **Latitudinal pattern:** Little changes in SA, while increased to south in TR and ST.

**Salinity**
- **Latitudinal pattern:** Little changes in SA and ST, while increased to south in TR
- **Annual pattern:** Higher in SA and TR during 1981-1988 and 1989-1997, respectively
Results: Latitudinal and annual changes in zooplankton abundance and biomass

**Abundance**

**Latitudinal pattern:**
Little latitudinal change

**Annual pattern:**
Higher in TR during 1998-2000

**Biomass**

**Latitudinal pattern:**
Clear latitudinal changes: Highest in TR, followed by SA and least in ST (TR > SA > ST)

**Annual pattern:**
Higher in SA and TR during 1998-2000
Results: Latitudinal and annual changes in zooplankton biomass with size class

Latitudinal pattern:
Clear latitudinal pattern varied with size class:
- Higher in SA and ST for 0-1 and 4-5 mm.
- Higher in TR for 1-2, 2-3 and 3-4 mm.

Annual pattern:
No clear annual pattern was detected for biomass at each size class.
Results: Latitudinal/annual changes in slope and intercept of NBSS

**Slope of NBSS**
- **Latitudinal pattern:** Clear latitudinal change, thus lower in TR.
- **Annual pattern:** There were no clear annual changes

**Intercept of NBSS**
- **Latitudinal pattern:** Clear latitudinal change, thus lower in TR.
- **Annual pattern:** There were no clear annual changes

Both slope and intercept of NBSS suggest that top down control dominated in TR.
Summary

Latitudinal changes
All parameters in this study (hydrography, zooplankton biomass and NBSS) showed clear latitudinal changes.

Highest biomass in TR was made by dominance of large-sized *Neocalanus* spp. C5 (ESD: 2-3 mm).

Highest biomass at TR region in the central North Pacific is corresponded with the cases in the western (Matsuno et al. 2009) and eastern (Saito et al. 2011) North Pacific. NBSS analysis revealed that the top down control dominated in TR.

Annual changes
No clear annual patterns were detected for zooplankton in this study.

Variability in the central North Pacific zooplankton dominated by latitude, yet was apparently consistent over inter-annual time scales.
Discussion: Latitudinal changes in zooplankton biomass

**Neocalanus**

C1-C3

C5

\( p < 0.001 \)

**N. plumchrus C5**

ESD (mm)

\[
\begin{array}{c}
\text{> 5} \\
\text{4-5} \\
\text{3-4} \\
\text{2-3} \\
\text{1-2} \\
\text{0-1} \\
\end{array}
\]

Biomass (mg DM m\(^{-2}\))

SA TR ST

Low Temperature (°C) High

Biomass: ST < SA < TR

Peak latitude shifted to south for large size class

Reflect of faster development of **Neocalanus** in the south

ESD 2-3 mm corresponds to **Neocalanus** spp. C5. They distributed both SA and TR, and higher temperature in TR may induce faster development.

Biomass was determined by what stage dominated for **Neocalanus**.
Discussion: Latitudinal changes in NBSS

NBSS in TR was characterized with low slope and intercept:
Top down control dominated in TR.

Top down control in TR was governed by dominance of *Neocalanus* spp. C5 there.

TR

Log Normalized biomass

(\(\text{g DM m}^{-3}\) weight \(\text{g DM}\))

Low

High

SA & ST

Log Biomass (\(\text{g ind.}^{-1}\))

Bottom up
Dominated by small-sized copepods

Top down
Reflect of large-sized copepods