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Chapter 3

COMPARISON OF MESOZOOPLANKTON BIOMASS DOWN TO THE GREATER DEPTHS (0-3000 M) BETWEEN 165°E AND 165°W IN THE NORTH PACIFIC OCEAN: THE CONTRIBUTION OF LARGE COPEPOD *NEOCALANUS CRISTATUS*

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ABSTRACT

While our knowledge about east-west differences in seasonal features of phytoplankton communities in the North Pacific ecosystem has advanced quickly in recent years (i.e. presence of phytoplankton spring bloom in the west while it absent in the east), little information is available on east-west differences in organisms at higher trophic level than phytoplankton. This is partly due to the differences in sampling methodologies for animals at higher trophic levels. In the present study, we evaluate east-west differences of zooplankton biomass down to the greater depths in the North Pacific employing the same method. We carried out zooplankton sampling with VMPS (60 µm mesh) down to the greater depths (six layers between 0 and 3000 m) at 19 stations between 36°N and 50°N along 165°E and 165°W in summers of 2003 and 2004. Half of the samples were filtered on 30 µm mesh and used for biomass determination. The other half samples were preserved with 5% borax-buffered formalin and used for microscopic observation. In the land laboratory, biomass determination was done for 8 mass-units (WM, DM, C, H, N, ash, AFDM and Energy). As taxonomic account, large calanoid copepod *Neocalanus cristatus* CV stage were enumerated and their biomass was determined by multiplying separately determined individual mass. Zooplankton biomass integrated over the 0-3000 m depth varied from 5.9 to 28.0 g DM m^{-2}, and was higher at high latitudes. From the viewpoint of east-west comparison, zooplankton biomass in the

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western (165˚E) stations was 1.7 times higher than that in the eastern (165˚W) stations consistently. As a taxonomic account, biomass of *N. cristatus* CV was greater at western stations (165˚E) than at eastern stations (165˚W), which reflected to the east-west differences in the whole zooplankton biomass. Carbon contents of *N. cristatus* CV individuals were higher for the individuals from 165˚E stations than those from 165˚W stations. These east-west differences in zooplankton biomass (high in west, low in east) may be interpreted by regional differences in phytoplankton abundance of both regions (high in west, low in east).

INTRODUCTION

In the pelagic ecosystem, mesozooplankton feed on phytoplankton, microzooplankton, other mesozooplankton and detritus. Since mesozooplankton produces large-sized fecal pellets, size and biomass of them are known to be primary important to determine amount of vertical particle flux (cf. Michaels and Silver 1988). Together with their contribution of vertical material flux, their contribution on remineralization of organic matter is also important. Hernández-León and Ikeda (2005) estimate global depth-integrated mesozooplankton respiration is 13.0 Gt C year^{-1}, which accounts to 17-32% of global primary production. From viewpoint of fisheries, mesozooplankton is a major food source of epipelagic fishes. Size and biomass of mesozooplankton effects on food selectivity of epipelagic fishes (Sheldon et al. 1977) and taxonomic (=chemical) contents of mesozooplankton effects on growth and survival of larvae (van der Meeren and Næss 1993). Thus, accurate estimation of biomass and chemical composition of mesozooplankton is a prime important from the viewpoints both biological oceanography and fisheries.

In the last decade, east-west differences of plankton community in the North Pacific are revealed. Thus, phytoplankton density and primary production are known to be higher in the western than those in the eastern North Pacific (Shiomoto and Asami 1999, Shiomoto and Hashimoto 2000). This east-west difference is considered to be caused by the differences in concentration of dissolved-iron (higher in the western) (Harrison et al. 1999, Suzuki et al. 2002). East-west differences in phytoplankton community assumed to effects zooplankton abundance, biomass, and community in these region (Mackas and Tsuda 1999), and higher transfer efficiency in the western region is suggested (Taniguchi 1999). For the dominant copepods in mesozooplankton community, east-west differences in life cycle (Kobari and Ikeda 2001, Padmavati et al. 2004, Tsuda et al. 2004, Shoden et al. 2005) and their body sizes (Tsuda et al. 2001, Kobari et al. 2003) are reported. However, there still remains whether the total mesozooplankton masses and chemical contents are varied between east and west or not. It is partly because of the differences in sampling device (i.e. mesh size, sampling period, sampling depth etc.) between east and west, which prevents direct comparison of biomass and chemical composition of mesozooplankton between east and west.

In the present study, mesozooplankton biomass and their chemical composition are quantified based on same method from sea surface to 3000 m at 36˚N-50˚N along 165˚E (western) and 165˚W (eastern) North Pacific. Addition to biomass and chemical components, as a taxonomic account, biomass and body size of large sized copepod *Neocalanus cristatus* CV in the samples are quantified to examine regional changes in taxonomic accounts and evaluate their effects on total mesozooplankton biomass.

MATERIAL AND METHODS

Field Sampling

Zooplankton samples were collected at 19 stations between 36°N and 50°N along 165°E and 165°W transects in the North Pacific Ocean during 1 July to 2 August of 2003 and 2004 (Figure 1). There were four (2003) or five (2004) stations along 165°E and three (2003) or seven (2004) stations along 165°W (Figure 1). At each station, stratified vertical sampling from six strata (0-50, 50-250, 250-500, 500-1000, 1000-2000 and 2000-3000 m) were made with 60-µm mesh and 0.25 m^2 (= 0.5 m x 0.5 m) mouth area Vertical Multiple Plankton Sampler (VMPS, Tsurumi Seiki Ltd., Terazaki and Tomatsu 1997) at night (stratified sampling by VMPS took ca. 3 hours and was made during 19:28-3:48 in local time). Towing speed of VMPS was 1 m s^{-1}, and the TSK flowmeter was mounted of the mouth of VMPS to monitor volume of filtered water. The filtering efficiency was mostly ca. 90%. At each station, CTD cast (SBE 19 plus) was also made down to 3000 m.

Collected zooplankton samples were split with three fractions (1/2, 1/4 and 1/4) by Motoda Splitting device (Motoda 1959). A 1/2 of the samples was preserved with 5% borax buffered formalin-seawater for latter microscopic observations, and the 1/4 aliquot was filtered through pre-weighed pieces of 30 µm mesh net under vacuum. Samples were then briefly rinsed with distilled water while still under vacuum, wrapped with aluminum foil, placed into sealed plastic bags, and stored in a deep freezer (-80°C).

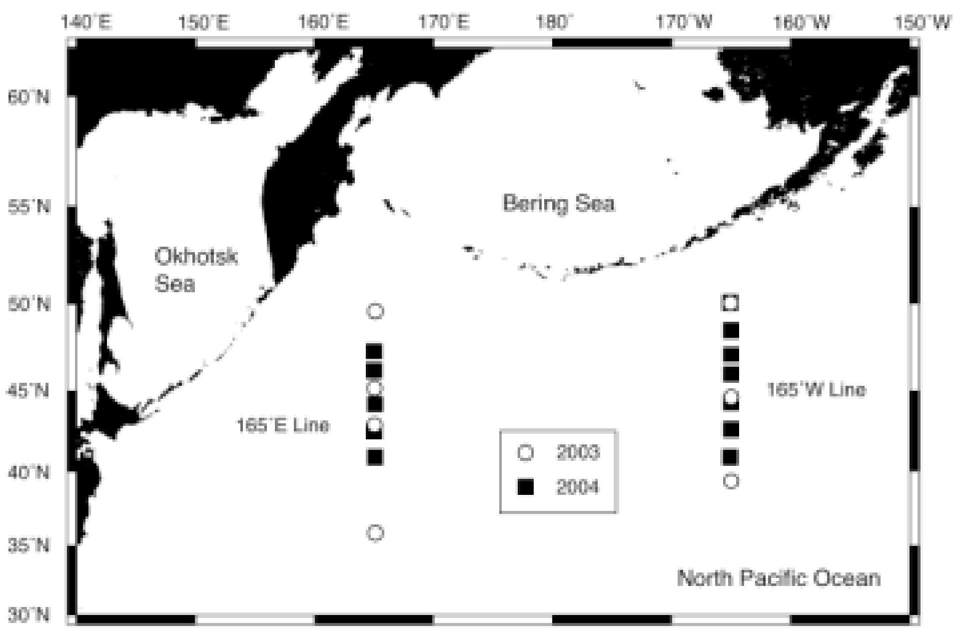

Figure 1. Location of sampling stations along 165°E and 165°W lines in the North Pacific Ocean in 2003 (open circle) and 2004 (solid square). There were four (165°E) and three (165°W) stations in 2003, while were five (165°E) and seven (165°W) stations in 2004.

The remaining 1/4 aliquot was used to sort fresh zooplankton especially copepod *Neocalanus cristatus* copepdid stage V (CV). Sorted *N. cristatus* CV was briefly rinsed with distilled water, placed on pre-weighed aluminum pan and also stored in a deep-freezer.

Chemical and Taxonomic Component

In the land laboratory, frozen zooplankton and *Neocalanus cristatus* CV samples were weighed (wet mass, WM) and then freeze-dried to obtain dry mass (DM). Water content in the samples was calculated from the difference between WM and DM, and expressed as a percentage of WM. Dried samples were ground into a fine powder with a ceramic mortar and pestle and used for analyses of carbon and nitrogen (Yanaco, CHN Corder MT-5). A weighed fraction of each sample was put into pre-weighed aluminum cup, then incinerated at 480˚C for 5 h and re-weighed for ash determination (ash), and ash-free dry mass (AFDM) fraction was calculated (AFDM= DM- ash). The energy content was calculated by using formulae given by Gnaiger (1983), amended by Gnaiger and Shick (1985): $J = 66.265W_C + 4.436W_N - 11.2$, where J is an energy content in J mg^{-1} AFDM, and W_C and W_N are fractions of C and N, respectively, on an AFDM basis.

As a taxonomic component, *Neocalanus cristatus* CV were counted with the formalin preserved samples. Using individual DM data at each station, biomass of *N. cristatus* CV were quantified (g DM m^{-2}) and expressed as percentage to total DM. The prosome length (PL) of *N. cristatus* CV in 2003 was measured to the nearest 0.2 mm under a dissecting microscope with an eye-piece micrometer.

Analysis of Biomass and Chemical Components

For chemical component analysis, a cluster analysis and non-metric multidimensional scaling (NMDS) ordination were made. Data (X) on masses (WM, DM, C, N, Ash and AFDM, all in mg m^{-3}), energy (J m^{-3}), and chemical contents (Water [%WM], C [%DM], N [%DM], C:N ratio [weight base], AFDM [%DM] and Energy [J mg^{-1} DM]) at each stratum were transformed to $\log_{10}(X+1)$ prior to analysis in order to reduce the bias of chemical components.

Similarities between samples were examined by the Bray-Curtis index (Bray and Curtis 1957) according to the differences in masses, energy and chemical components. For grouping the samples, the similarity indices were coupled with hierarchical agglomerative clustering with a complete linkage method. The NMDS ordination was carried out to delineate the sample groups on the two-dimensional map. All of these analyses were carried out using BIOSTAT II software (Sigma Soft). To evaluate differences in biomass and chemical composition between groups, one-way ANOVA and post-hoc test with Fisher's PLSD were employed.

RESULTS

Hydrography

Sea surface temperature varied from 7.9˚C (49˚30'N, 165˚00E in 2003) to 20.3˚C (36˚00'N, 165˚00'E in 2003) (Figure 2). Both 2003 and 2004, the 6˚C isothermal contours down to 250 m around at 42˚30'N in the 165˚E, while they down to 250 m around at 46˚00'N in the 165˚W. Thus, temperature conditions in 165˚W were warmer than those in 165˚E. Both 165˚E and 165˚W, temperature decreased with increasing depth, and was <3˚C below 1000 m throughout the region.

Salinities varied from 32.4 PSU (50˚N, 165˚W in 2004) to 34.5 PSU (36˚00'N, 165˚00'E in 2003) (Figure 2). Both 2003 and 2004, the 33.6 PSU isoline reached sea surface around at 42˚30'N in the 165˚E, while they around at 41˚00'N in the 165˚W. Thus, salinity conditions near surface in 165˚W were less saline than those in 165˚E. Both 165˚E and 165˚W, salinity increased with increasing depth, and was >34.5 below 1500 m throughout the region.

Based on criteria of Favorite et al. (1976), subarctic front (SF, northern end of transition domain) and subarctic boundary (SB, southern end of transition domain) were identified. Both 2003 and 2004, the SF located at around 44˚N in the 165˚E, while was at around 47˚N in the 165˚W (Figure 2).

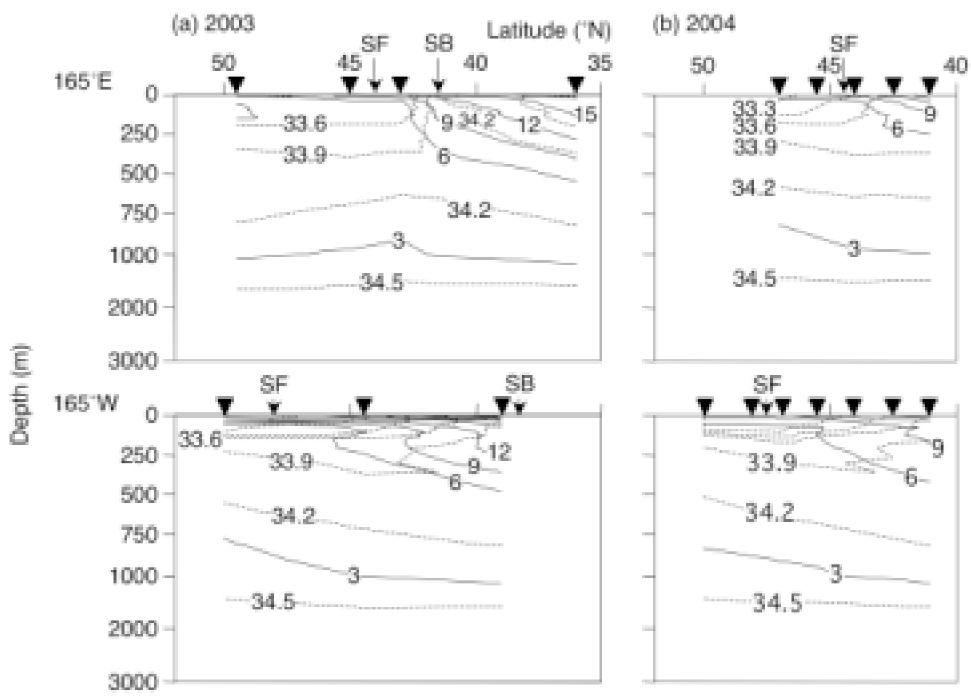

Figure 2. Vertical structures of temperature (solid line) and salinity (dashed line) along 165˚E (upper) and 165˚W (lower) in the North Pacific Ocean in 2003 (a) and 2004 (b). Note that the depth intervals are varied between upper and lower of 1000 m depth. Solid triangles indicate sampling stations. Approximate positions of subarctic front (SF) and subarctic boundary (SB) are marked with arrows.

In 2003, SB detected at 42˚N in 165˚E, while was at 38˚N in 165˚W. Note that SB was not detected in 2004, because of the limited latitudinal study area (41˚N-50˚N) in this year. Thus the northern end of transition domain (SF) in 165˚W was located northward than that in 165˚W.

Zooplankton Mass and Chemical Composition

Zooplankton dry masses throughout the 0-3000 m depths were varied between 5.9 g DM m^{-2} (39˚00'N, 165˚W in 2003) and 28.0 g DM m^{-2} (47˚00'N, 165˚E in 2004) (Figure 3). Both 2003 and 2004, zooplankton mass was greatest in the highest latitude stations and was decreased with decreasing latitudes. Compare within the same latitude, zooplankton mass was consistently greater in 165˚E than that in 165˚W, and this phenomenon was also the case of other mass unit (data not shown). Factor between masses in 165˚E and 165˚W (values in 165˚E: 165˚W) was varied between 1.4-1.9 (mean±1sd: 1.7±0.2).

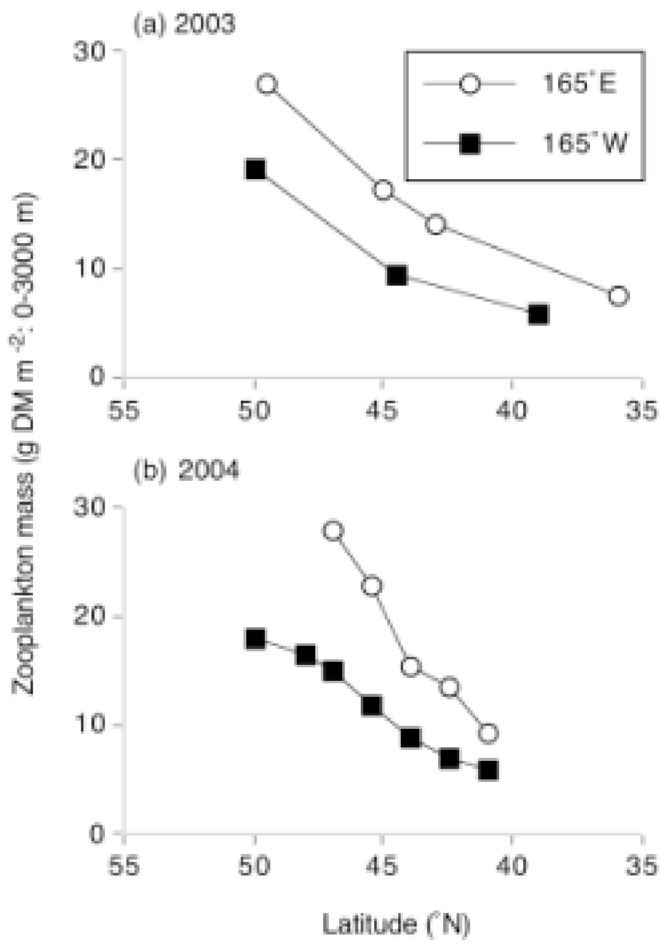

Figure 3. Latitudinal changes in zooplankton mass throughout 0-3000 m water column along 165˚E (open circle) and 165˚W (solid square) in the North Pacific in 2003 (a) and 2004 (b).

Cluster analysis based on the masses and chemical contents of each sample showed that zooplankton communities could be divided into five groups (A-E) at 18% Bray-Curtis dissimilarity (Figure 4). Two-dimensional NMDS plots showed that these groups were well separated from each other (Figure 4). As an environmental parameter, significant multiple regression with the NMDS ordination scores was observed for depth (r^2=0.61, p<0.001) and latitude (r^2=0.07, p<0.05). The directions of the arrows indicate that groups A-D occurred in the order of from shallow to deep: e.g. A<B<C<D (Figure 4).

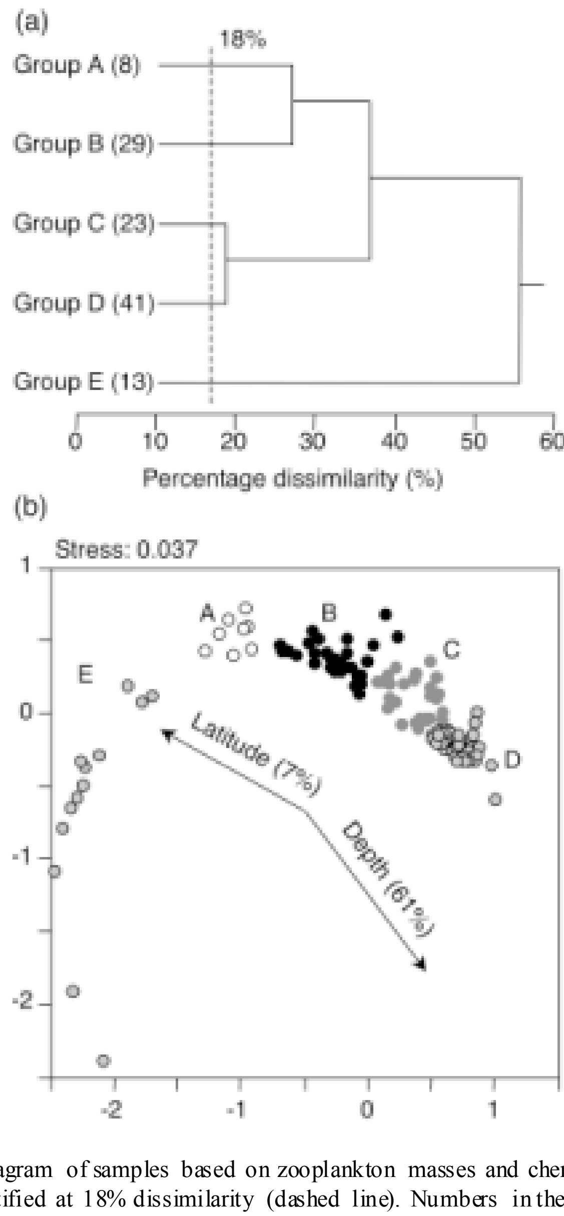

Figure 4. (a): Cluster diagram of samples based on zooplankton masses and chemical contents. Five groups (A-E) were identified at 18% dissimilarity (dashed line). Numbers in the parentheses indicate sample number each group contains. (b): NMDS ordination of samples with the five zooplankton groups derived by cluster analysis. Arrows indicate multiple regressions between ordination scores and environmental variables (p<0.05), squared multiple r were shown as percentages.

Latitudinal and vertical distribution of each zooplankton community showed that the group D occurred in the bathypelagic layer (1000-3000 m) in most of the stations (Figure 5).

Group B and C mainly occurred in the mesopelagic layer (200-1000 m) and commonly the group B occurred shallower than the group C. In the epipelagic layer (0-200 m), the shallowest depth (0-50 m) was dominated by group A and E. Distribution of group A and E separated latitudinal: i.e. the group E was seen mainly in the northern area (ca. >43°N) while the group A in the southern area (<43°N) (Figure 5).

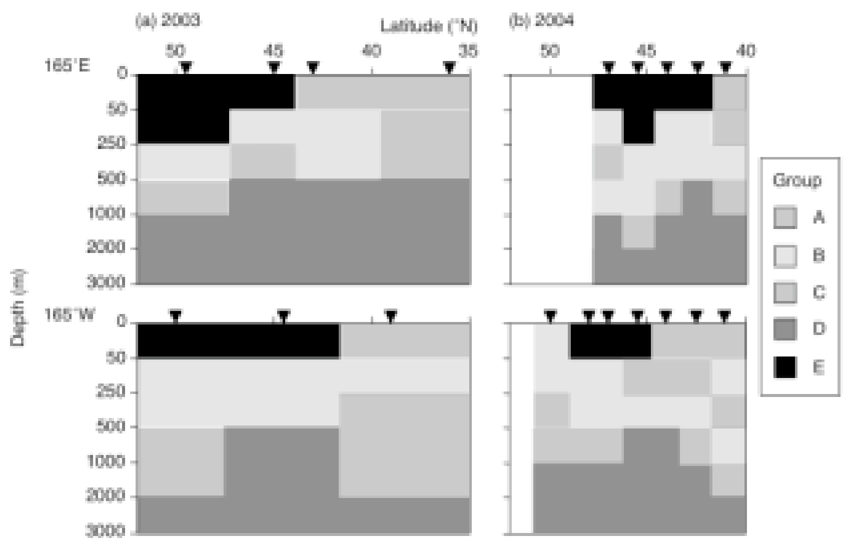

Figure 5. Latitudinal and vertical distribution of five zooplankton community groups (A-E) identified by Bray-Curtis similarity index data (cf. Figure 4) at 165°E (upper) and 165°W (lower) in 2003 (a) and 2004 (b). Triangles indicate sampling stations.

Most of the masses, energy and chemical contents showed significant differences between groups (Table 1). Masses and energy showed similar pattern, thus the group E was characterized by significantly greater than the other groups.

Values in masses and energy was in the order of E>A>B>C>D, which was same to the order of vertical distribution of each group from shallow to deep (cf. Figure 5).

Chemical contents of group E and A were comparable. Thus, the group E characterized by low Water, high C, N, AFDM and Energy contents, while the group A characterized by high Water, low C, N, AFDM and Energy contents (Table 1).

Taxonomic Component (*Neocalanus Cristatus*)

Biomass of *Neocalanus cristatus* CV varied between 0.07 g DM m^{-2} (36°00'N, 165°00'E in 2003) and 6.4 g DM m^{-2} (47°00'N, 165°00'E in 2004) (Figure 6).

Table 1. Masses, energy and chemical contents of zooplankton samples in the North Pacific down to 3000 m depths

	Group					one-way	Post-hoc test by Fisher's PLSD
	A (*n*=6)	B (*n*=30)	C (*n*=23)	D (*n*=41)	E (*n*=14)	ANOVA	
Masses (mg m^{-3})							
Wet (WM)	289±64	114±44	45±18	11±6	1026±967	***	D C B A E
Dry (DM)	31.4±6.2	13.1±4.4	5.0±1.7	1.3±0.7	126.3±99.6	***	D C B A E
Carbon (C)	11.09±1.77	5.67±1.70	2.12±0.75	0.57±0.34	56.36±42.07	***	D C B A E
Nitrogen (N)	2.25±0.48	1.07±0.37	0.41±0.16	0.11±0.07	10.07±6.92	***	D C B A E
Ash (Ash)	9.96±5.33	2.82±1.65	1.12±0.56	0.26±0.13	22.85±29.42	***	D C B A E
Ash-free dry (AFDM)	21.5±3.5	10.3±3.4	3.9±1.4	1.0±0.6	103.4±75.7	***	D C B A E
Energy (J m^{-3})	504±81	265±77	99±35	26±16	2620±1973	***	D C B A E

Table 1. (Continued)

	Group					one-way	Post-hoc test by Fisher's PLSD				
	A (*n*=6)	B (*n*=30)	C (*n*=23)	D (*n*=41)	E (*n*=14)	ANOVA					
Chemical content											
Water (%WM)	88.5±4.6	87.8±3.0	88.2±3.1	89.8±2.6	86.9±3.1	**	E	B	C	A	D
C (%DM)	36.0±6.9	43.9±6.6	42.6±6.5	42.7±4.5	44.9±7.3	**	A	C	D	B	E
N (%DM)	7.29±1.50	8.15±0.80	8.16±0.90	8.12±0.94	8.27±0.85	*	A	D	B	C	E
C:N ratio (weight base)	4.97±0.52	5.42±0.82	5.26±0.84	5.19±0.56	5.52±0.77	ns					
AFDM (%DM)	69.6±12.5	78.8±9.0	77.8±7.6	74.6±15.9	82.6±9.8	*	A	D	C	B	E
Energy (J mg^{-1} DM)	16.4±3.2	20.6±3.5	19.9±3.5	19.9±2.3	20.9±3.8	**	A	C	D	B	E

Based on Bray-Curtis similarity index by log-transformed data, zooplankton samples were separated into five groups (A-E, cf. Figure 4).
Values are mean±1sd. Between group differences was tested with one-way ANOVA and post-hoc test (Fisher's PLSD).
Any two groups not connected by underline are significantly different ($p<0.05$).
*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$, ns: not significant, *n*: number of samples included.

Both 2003 and 2004, *N. cristatus* CV mass was greatest in the highest latitude stations and was decreased with decreasing latitudes. Compare within the same latitude, *N. cristatus* CV mass was consistently greater in 165˚E than that in 165˚W. Factor between *N. cristatus* CV mass in 165˚E and 165˚W (values in 165˚E: 165˚W) was varied between 1.2-13.6 (mean: 4.5).

Composition of *Neocalanus cristatus* CV to total zooplankton mass varied between 1.1% (39˚00'N, 165˚00'W in 2003) and 60.6% (48˚00'N, 165˚00'W in 2004) (Figure 6). Common to 2003 and 2004, composition of *N. cristatus* CV to total zooplankton mass was greater in the highest latitude stations and was decreased with decreasing latitudes. East-west differences in composition of *N. cristatus* to total zooplankton mass were not so evident (Figure 6).

Individual prosome length of *Neocalanus cristatus* CV varied between 5.8±0.3 mm (39˚00'N, 165˚00'W) and 6.9±0.3 mm (49˚30'N, 165˚00'E) (Figure 7). Both in 165˚E and 165˚W, prosome length of *N. cristatus* was larger in the high latitudes and decreased with decreasing latitudes. Carbon content of *N. cristatus* CV varied between 0.62 mg C ind^{-1} (36˚00'N, 165˚00'E in 2003) and 4.49 mg C ind^{-1} (49˚30'N, 165˚00'E in 2003) (Figure 7). In most of the stations, carbon content of *N. cristatus* individual was greater in the high latitude stations, and was greater in the 165˚E within the same latitude, while it was not the case of southern end of 165˚W in 2004 (42˚30'N and 41˚00'N).

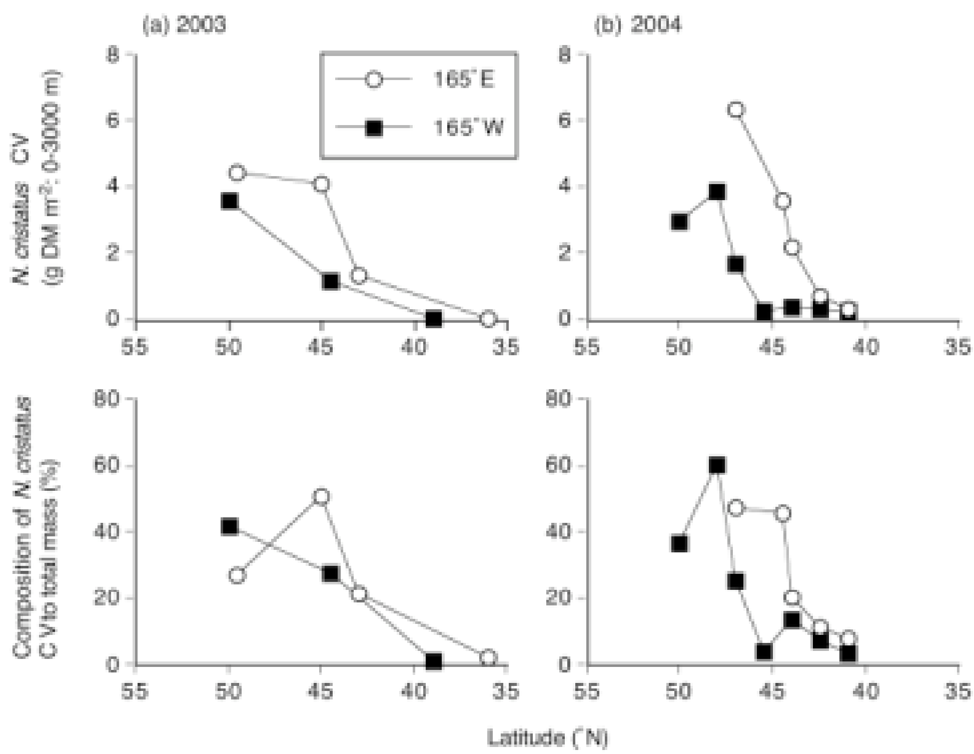

Figure 6. Latitudinal changes in biomass (dry mass) of copepod *Neocalanus cristatus* CV (upper) and their contribution (%) to total mesozooplankton mass (lower) during 2003 (a) and 2004 (b).

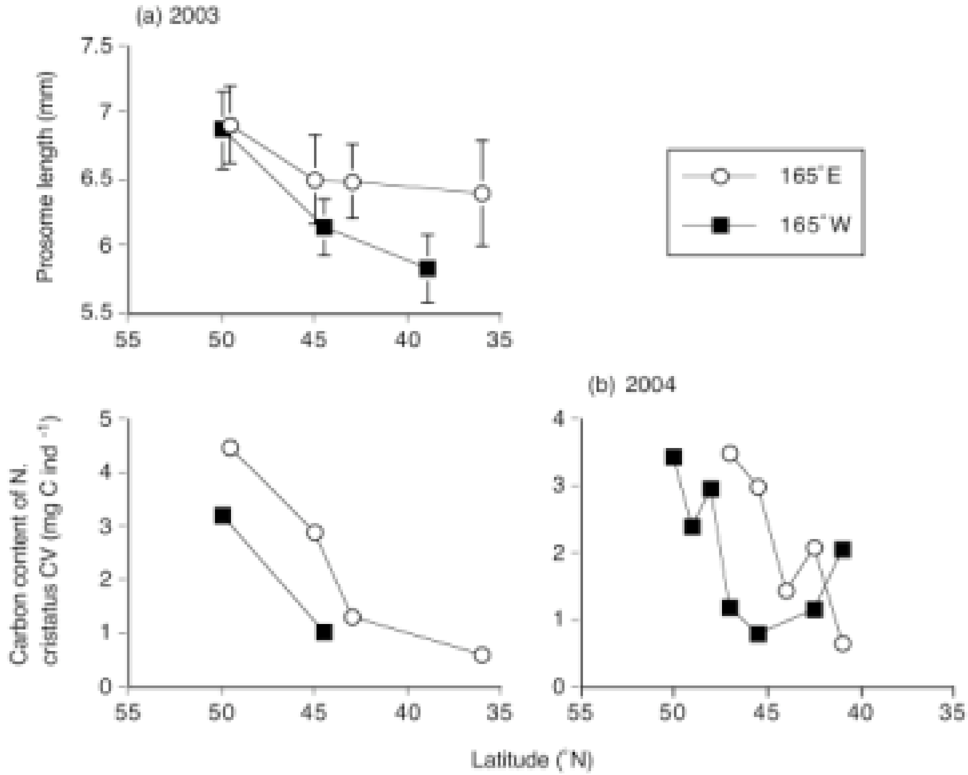

Figure 7. Latitudinal changes in prosome length (upper) and carbon content (lower) of *Neocalanus cristatus* CV during 2003 (a) and 2004 (b). Note that there are no data on prosome length in 2004. Vertical bars in prosome length indicate standard deviations.

DISCUSSION

Total Zooplankton Mass

Total zooplankton mass observed in this study (5.9-28.0 g DM m^{-2}) is falls within values (1.3-27.4 g DM m^{-2}) reported from 0-5800 m of 44°N-25°N in the western North Pacific (Yamaguchi et al. 2005). In both 2003 and 2004, zooplankton masses were greater in the high latitude and were greater in the western (165˚E) than those in the eastern (165˚W) by a factor of 1.7 (Figure 3). These east-west differences in zooplankton masses are the first record in this region. What is the cause of these east-west differences? In terms of east-west differences in zooplankton ecology, life cycle pattern (presence of quiescence or not, growth and reproduction timing, and number of generation per year) of dominant copepods (*Neocalanus flemingeri*: Kobari and Ikeda 2001, *Eucalanus bungii*: Tsuda et al. 2004; Shoden et al. 2005, *Metridia pacifica*: Padmavati et al. 2004) and their body sizes (Tsuda et al. 2001, Kobari et al. 2003) are reported. Life cycle of copepods in the western subarctic Pacific is longer (*N. flemingeri*: Kobari and Ikeda 2001, *M. pacifica*: Padmavati et al. 2004) or shorter (*E. bungii*: Shoden et al. 2005) than those in the eastern Pacific. Longer generation length in the western region is attributed to the low temperature in the western region (Oyashio region) than that in the eastern region (Gulf of Alaska), while shorter generation length in the western region is considered to be related higher primary production in the western region than that in the eastern region. Body sizes of copepods are commonly larger in the western region than those in the eastern region, and are considered to be caused by the low temperature in the western region (Tsuda et al. 2001, Kobari et al. 2003). These large body sizes of dominant copepods in the western subarctic Pacific may be the cause of large zooplankton mass in the western region. For *Neocalanus* copepods, body size (prosome length) is varied regional by a factor of 1.22-1.25 (cf. Kobari and Ikeda 1999, 2001). If we assume masses varied with cubic body size, the difference in body size implies difference in mass by a factor of 1.8-1.9 (= 1.22^3 or 1.25^3). These values are close to the factor of zooplankton mass between western and eastern North Pacific observed in this study (1.7, Figure 3). In deed, factor between *Neocalanus cristatus* CV individual mass in 165˚E and 165˚W (values in 165˚E: 165˚W) was 4.5 observed (cf. Figure 7).

Chemical Contents

While the total zooplankton masses varied between east and west, their chemical components are similar between east and west. Chemical components of zooplankton showed latitudinal trends (group E in the north and group A in the south) in the upper epipelagic zone (0-50 m, Figure 5) and had vertical trends (from shallow to deep: group B<C<D, Figs. 4 and 5). The boundaries between group A and E in the upper epipelagic zone was corresponded to the subarctc front (SF) at 165˚E in 2003 (Figure 2), while was at transition domain (region between SF and subarctic boundary [SB]) in the other transect/year (Figure 5). Since zooplankton community in the transition domain is known to have characteristics of subarctic fauna (cf. Kobari et al. 2003), the zooplankton communities of group A and E is considered to be those of subtropical and subarctic groups, respectively.

Interestingly, chemical contents of group A and E were very comparable, thus the group A was characterized by high water and low C, N, AFDM and energy, while the group E was characterized by low water and high C, N, AFDM and energy (Table 1). The differences in these chemical contents are considered to be caused by the differences in dominant zooplankton taxa (fauna). In the North Pacific, the subarctic fauna is characterized by the dominance of large grazing copepods which known to accumulate massive lipids in their body (= low water and high C and AFDM, cf. Omori 1970, Ikeda et al. 2004). While the subtropical fauna is characterized by the dominance of gelatinous pelagic tunicates (i.e. salps and doliolids) which contains high water and low C and AFDM (Bone 1998, Postel et al. 2000). These differences in zooplankton fauna between subarctic and subtropical region, may induced latitudinal gradients in chemical composition.

In terms of vertical changes, chemical contents of groups B, C and D are not so different, but masses (WM, DM, C, N, ash, and AFDM) and energy showed similar gradients across them, thus all in the order of B>C>D (Table 1). It indicates that the group separation of group B, C and D is mainly caused by the values of masses but not by the chemical contents.

Taxonomic Accounts

Both in 2003 and 2004, biomass of *Neocalanus cristatus* CV was consistently greater in the western than that in the eastern North Pacific (Figure 6). It suggests that this east-west gradient (greater in the western) is a common phenomenon continues year-round. Contribution of *N. cristatus* CV to total mesozooplankton mass was greater in the northern stations and reached 40-60%. Diapausing copepods (*Neocalanus* spp. and *Eucalanus bungii*) is known to contribute 70% of copepod mass in the subarctic Pacific (Yamaguchi et al. 2002a), they induce dominance (47-52%) of metazooplankton to whole plankton mass in this region (Yamaguchi et al. 2002b, 2004). In the present study, in 2004 when the sampling stations located with fine scale (every 45'N), region where the high *N. cristatus* contributed (>20% of total mass) was at north of 46˚N at 165˚W, while was at north of 43˚N at 165˚E (Figure 6). Thus, the high *N. cristatus* region located more north in 165˚W than that in 165˚E, it may related to the subarctic front (SF) in 165˚W was located more north than that in 165˚E (Figure 2).

Body size of copepods is known to have negative relationship between their habitat temperatures (cf. Mauchline 1998). In the present study, prosome length of *Neocalanus cristatus* CV was larger in the northern stations and compared within the same latitude, it was larger in the western (165˚E) region (Figure 7). It may imply large carbon content per individual in the northern station and western (165˚E) stations (Figure 7). In 2004, there are no data on prosome length, while there are similar patterns (larger in the northern and western stations) except southern two stations in 165˚W.

CONCLUSION

In the present study, total zooplankton masses were consistently greater in the western (165˚E) North Pacific (Figure 3). It may caused by the dominance of large sized copepod *Neocalanus cristatus* CV in the western Pacific (Figure 6) and together with their large body size (which implies greater masses) in the western region (Figure 7). This large body size of *N. cristatus* CV may related to the low temperature condition in the western North Pacific (Figure 2). In the last decade, east-west differences in plankton community of the North Pacific are reported. Thus, phytoplankton density and primary production are known to be higher in the western than those in the eastern North Pacific (Shiomoto and Asami 1999, Shiomoto and Hashimoto 2000). This east-west difference is considered to be caused by the differences in concentration of dissolved-iron (higher in the western) (Harrison et al. 1999, Suzuki et al. 2002). East-west differences in phytoplankton community effects zooplankton abundance, biomass, and community in these region (Mackas and Tsuda 1999), and higher transfer efficiency in the western region is suggested (Taniguchi 1999). The consistently greater mesozooplankton masses in the western North Pacific in this study indicate these east-west differences is a common phenomenon throughout the lower trophic level of the North Pacific Ocean.

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