Diel vertical migration and carbon flux estimation on macrozooplankton in the summer western North Pacific

Atsushi Yamaguchi, Yurika Hanamiya, Hikaru Watanabe and Hiroto Murase

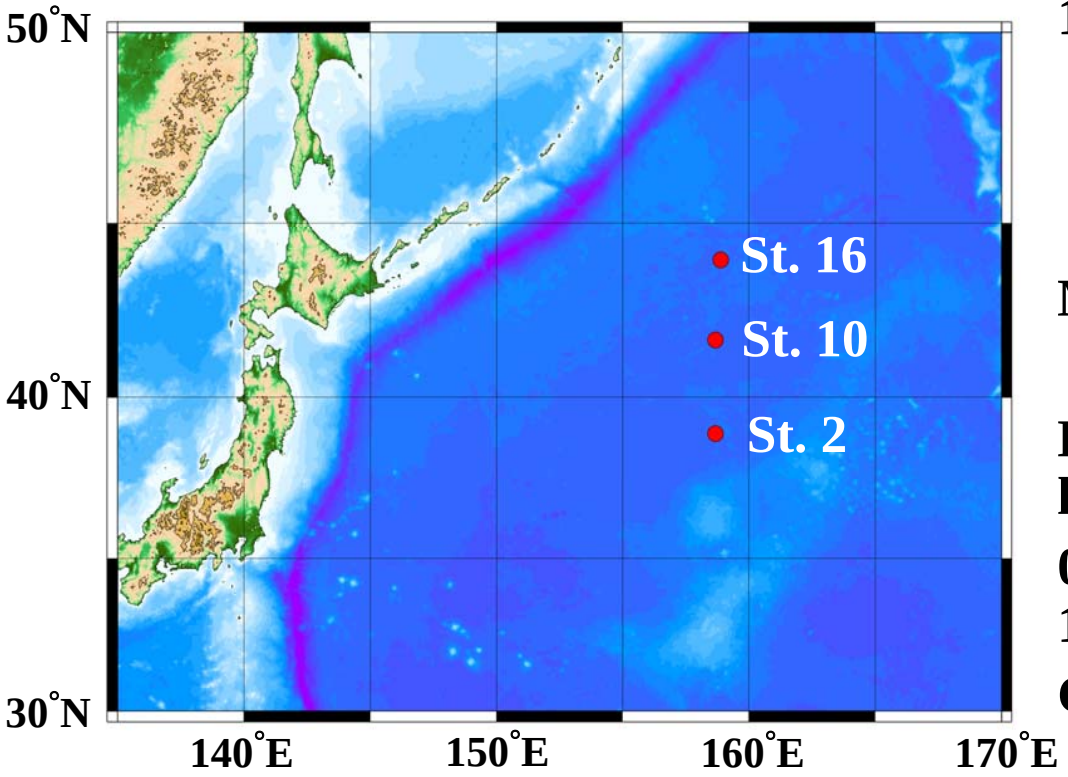
1: Hokkaido Univ., 2: Natl. Res. Inst. Far Seas Fish. 3:Inst. Cetacean Res.

Key words: Amphipods, Euphausiids, DVM, Biological pump

Amphipods

Euphausiids

1: Sampling & analysis



15-25 June 2003, R/V Shunyo Maru

St. 2 (38°54'N, 158°41'E)

St. 10 (41°41'N, 158°40'E)

St. 16 (43°58'N, 158°53'E)

MOCNESS (mouse area: 1 m^2, mesh size: 0.335 mm)

Day and night sampling from 8 layers between 0-250 m:

0-20, 20-40, 40-60, 60-80, 80-100, 100-150,150-200, 200-250 m

CTD cast: temperature and salinity

Analysis on samples:

From 10% formalin preserved samples: species identification, enumeration and body size measurement

Dry weight measurement (dominant 7 amphipods and 5 euphausiids): length-weight relationships

2: Estimation of carbon flux

B: dry weight (mg)

T: temperature (°C)

R_{100} and R_{400}: R at 100 and 400 m calculated from T_{100} and T_{400}

Daytime respiration and nighttime ingestion

- **Daytime respiration (R_{day}: mg C ind.$^{-1}$ day^{-1})**

$$\mathrm{Ln}\ R = -0.2512 + 0.7886\ \mathrm{Ln}B + 0.049T$$ (Ikeda 1985)

$$R_{day} = R_{400} \times 12/22.4 \times 0.97 \times 1/1000\ h_{day}$$

- **Nighttime ingestion (I: mg C ind.$^{-1}$ day^{-1})**

$$I = R_{100} \times 12/22.4 \times 0.97 \times 1/0.4 \times 1/1000\ h_{night}$$

(assuming GGE and NGE as 70% and 30%, respectively; Ikeda and Motoda 1978)

Estimation of duration time (h_{day} and h_{night})

Day: night = 15h: 9h (mean of local time)

Magnitude of migration: 300 m

Speed of migration (s: m h^{-1})

s = body length in mm x 28.8 (Kils, 1979)

Required time for migration (h_m)

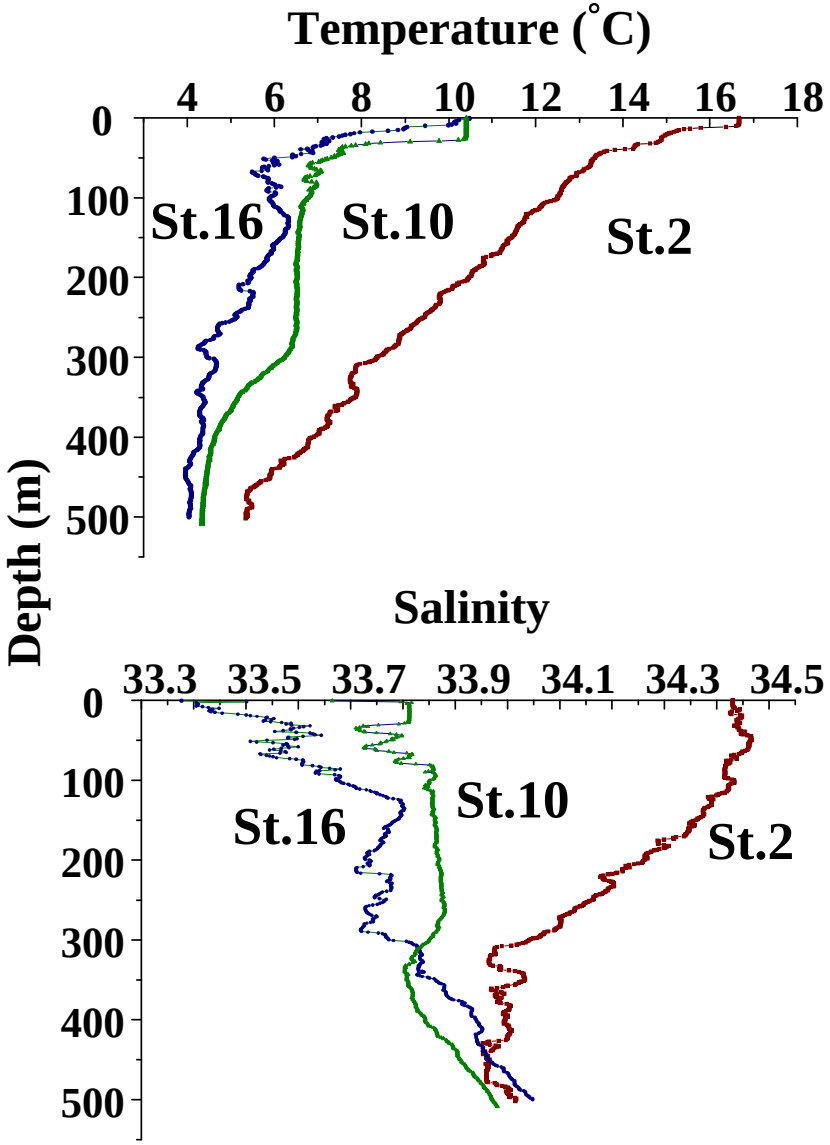
$$h_m = 300 / s$$

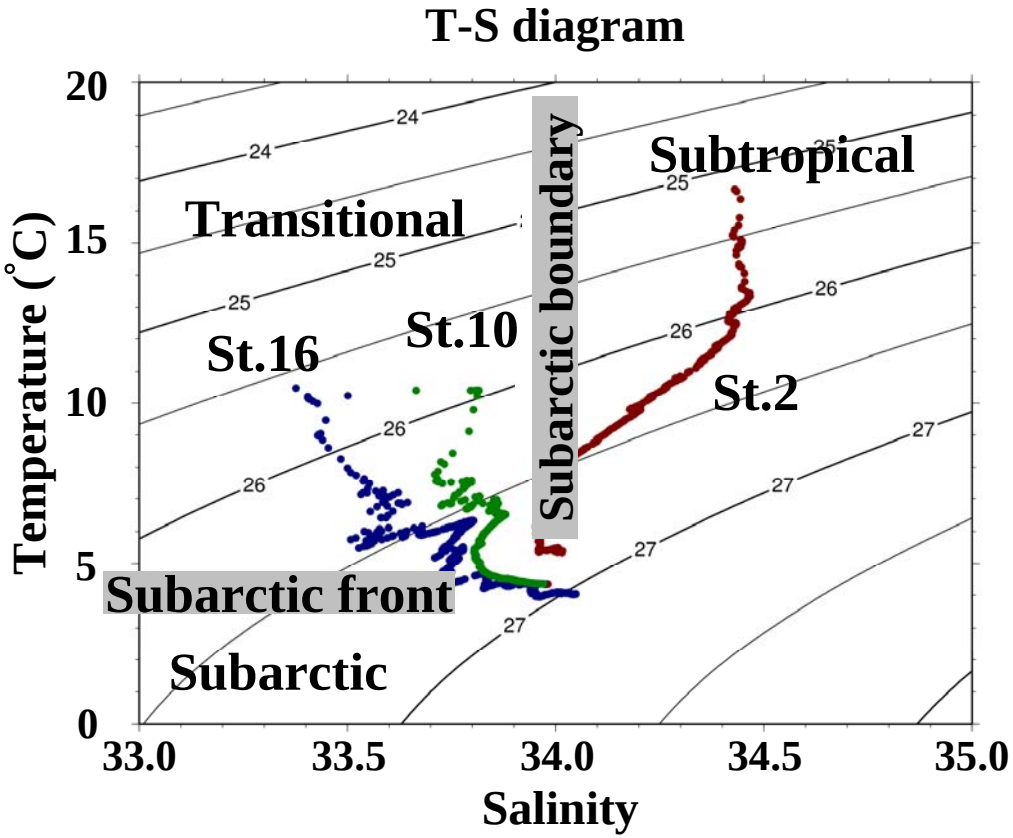
Duration time at deep layer (h_{day}) and surface layer (h_{night})

$$h_{day} = 15 - h_m$$

$$h_{night} = 9 - h_m$$

3: Results-temperature and salinity





St. 2 : Subtropical region
St. 10: Transitional domain
St. 16: Transitional domain

4: Results-amphipod abundance

Species	Abundance (inds. m^{-2})					
	St. 2		St. 10		St. 16	
	Day	Night	Day	Night	Day	Night
Cranocephalus sclerrotics		0.08				
Cyphocaris challengeri		0.69	0.11	98.44		28.01
Eupronoe minuta	4.53	3.31				
Hypenoides longipes		0.07				
Hyperia medusarum				0.72		
Hyperoche medusarum				0.18		
Mimonectes loveni		0.08				
Oxcephalus clausi		0.07				
Paraphronima crassipes		0.07		2.79		0.37
Paraphronima gracilis	0.34	0.28		2.79	0.26	0.94
Phronima atlantica	8.11	5.45	1.26	23.29	1.42	2.36
Phronima colletti		0.26				0.50
Phronima sedentaria	6.79	6.54	1.40	4.39	1.62	3.05
Phronima spp.	31.97	7.80				
Phronima stebbingi	0.62					
Phrosina semilunata	0.11	0.23				
Platyscelus seriatulus		0.12				
Primno abyssaris	2.27	0.35	6.70	13.81	1.67	1.22
Scina crassicormis				2.79		
Streetsia steerstrupi	0.34	0.21				
Themisto pacifica	4.70	6.31	194.58	4738.60	568.93	315.85
Vibilia austrails		0.08				
Vibilia caeca				5.57	0.08	0.18
Vibilia gibbosa		2.29	0.42	323.83	0.48	95.02
Vibilia pyripes		0.85				0.57
Vibilia viatrix				11.42		
Total amphipods	59.8	35.1	204.5	5228.6	574.47	448.1

17 genera 25 species

High diversity at night in subtropical region

Dominant species:

Subtropical region

Phronima spp.

Transitional domain

Themisto pacifica

Greater abundance at night (DVM):

Cyphocaris challengeri

Themisto pacifica

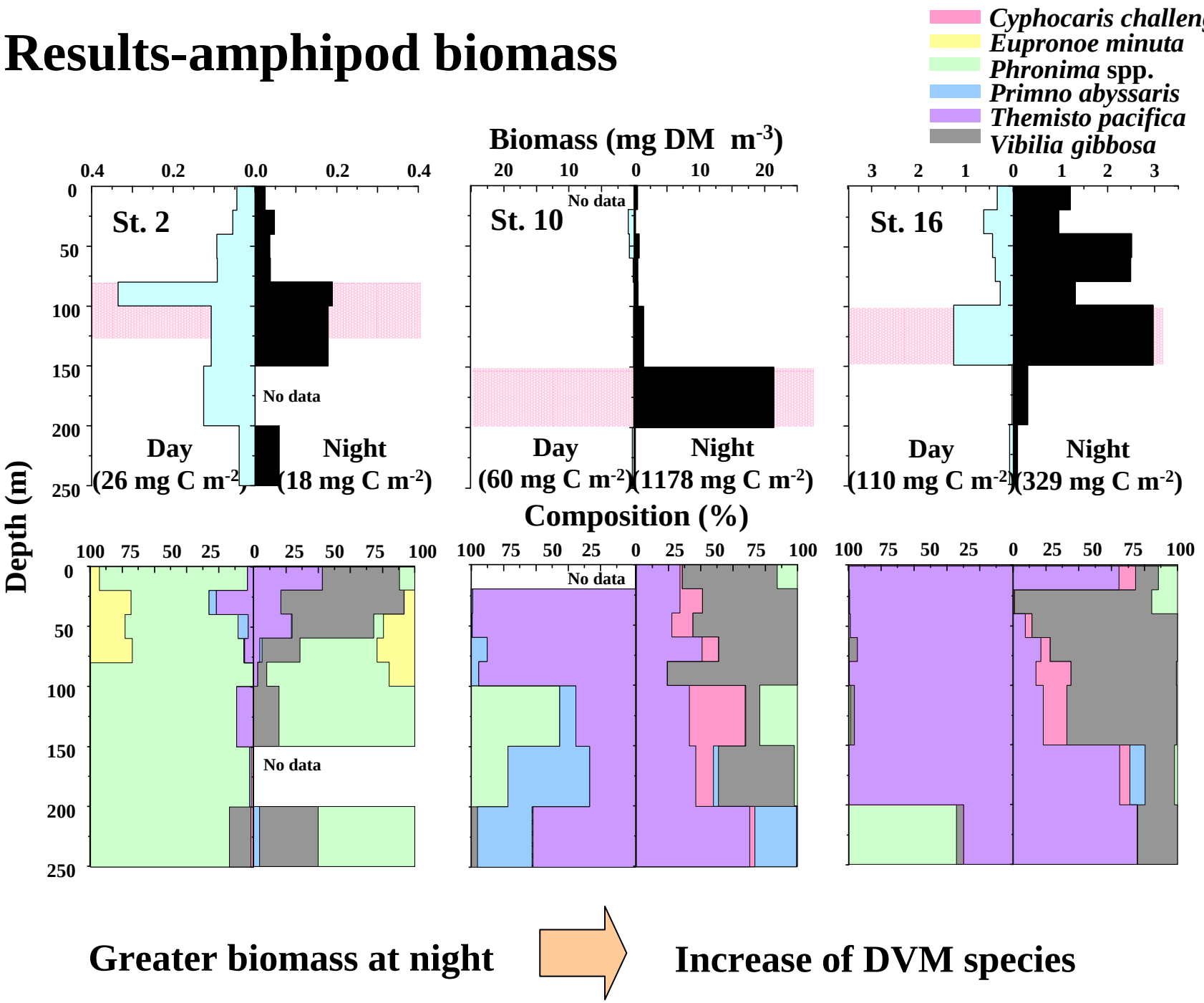
Vibilia gibbosa

Cyphocaris challengeri

Themisto pacifica

Vibilia gibbosa

5: Results-amphipod biomass



Greater biomass at night → **Increase of DVM species**

6: Results-euphausiid abundance

Species	Abandance (inds. m^{-2})					
	St. 2		St. 10		St. 16	
	Day	Night	Day	Night	Day	Night
Euphausia brevis	0.26					
Euphausia diomedeae	0.87	0.28				
Euphausia hemigibba	0.81	0.16				
Euphausia mutica	0.78	1.29				
Euphausia pacifica	68.18	166.09	2.62	203.77	5.58	41.39
Euphausia pseudogibba	2.08	22.80				
Euphausia recurva	4.43	6.32				
Euphausia similis	1.17	9.19				
Euphausia spp.	97.80	16.14	0.42	45.25		5.07
Nematobrachion flexipes	1.05	1.83				
Nematoscelis difficilis	0.13	11.81				
Nematoscelis spp.	0.59	1.92				
Stylocheiron abbreviatum						0.12
Stylocheiron carinatum				0.19	0.11	
Stylocheiron elongatum		0.07				
Stylocheiron longicorne	5.28	9.74		0.23	0.36	0.19
Stylocheiron maximum						0.13
Stylocheiron spp.	4.17	1.85	2.17	3.18	7.15	3.17
Tessarabrachion oculatum	4.59	3.58	4.16	12.22	4.08	7.60
Thysanoessa inspinata	0.90	0.87	1.97	16.49	23.52	23.60
Thysanoessa longipes					1.14	0.10
Thysanoessa spp.	3.54	13.85	12.49	1705.57	192.76	611.12
Thysanopoda aequalis		0.16				
Unidentified euphausiids	135.68	18.05	56.01	169.11	147.06	128.50
Total euphausiids	332.3	286.0	79.8	2156.0	381.8	821.0

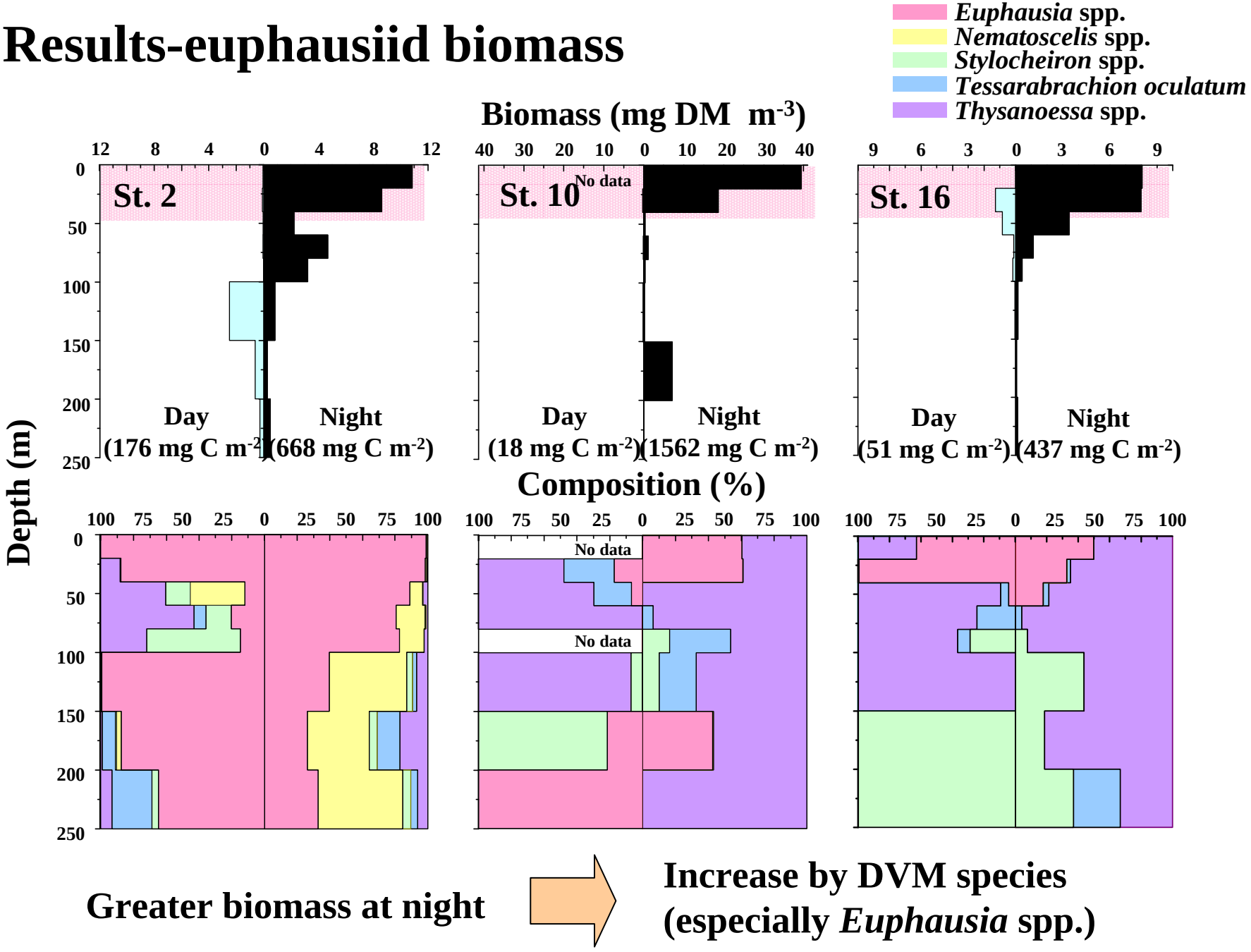
7 genera 19 species
High diversity in subtropical region
Dominant species: Subtropical region
***Euphaudia* spp.**
Transitional domain
***Thysanoessa* spp.**
Greater abundance at night (DVM):
Euphausia pacifica
Nematoscelis difficilis
***Thysanoessa* spp.**

Euphasia pacifica

Nematoscelis difficilis

Thysanoessa inspinata

7: Results-euphausiid biomass

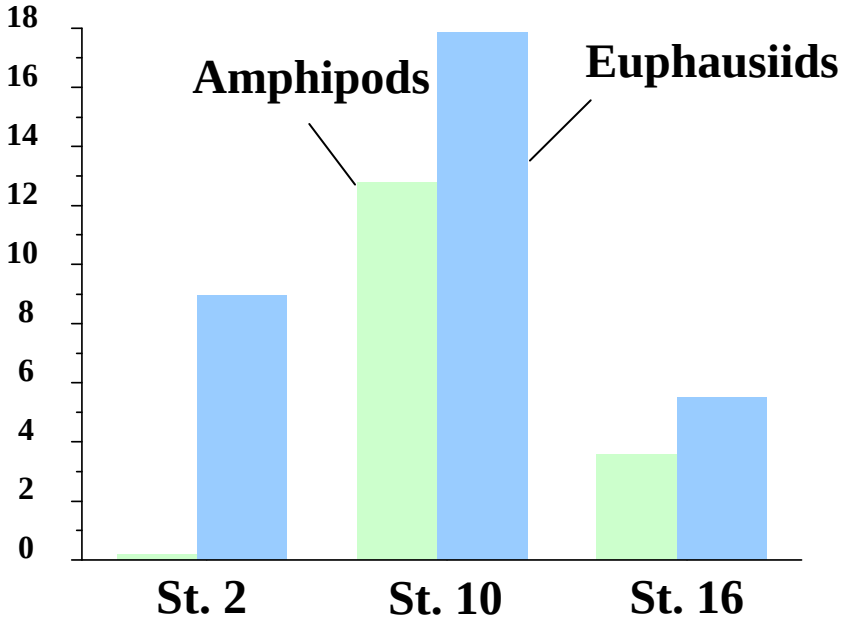


Greater biomass at night

Increase by DVM species (especially *Euphausia* spp.)

8: Results-estimated carbon flux

Ingestion (mg C m^{-2} day^{-1})

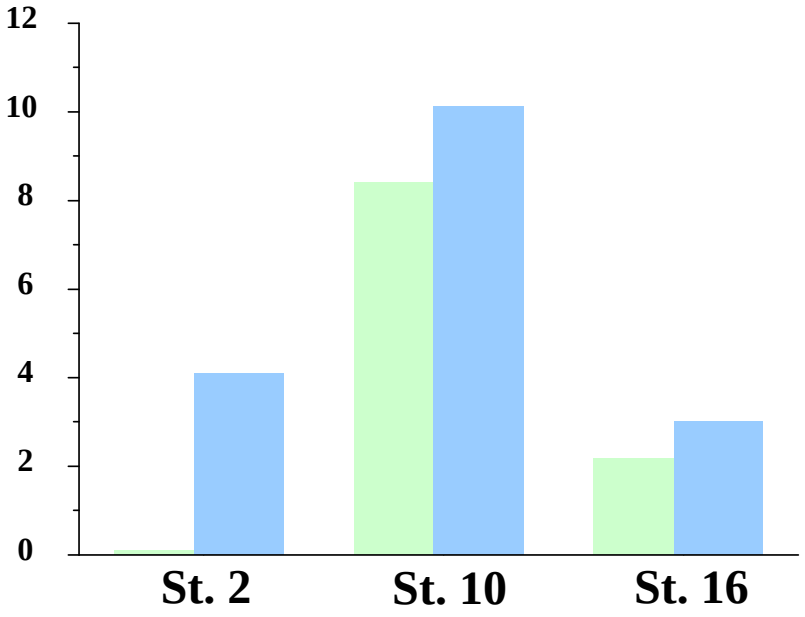


Total: 9-31 mg C m^{-2} day^{-1}

Primary production at St. Knot (44°N, 155°E): 227 mg C m^{-2} day^{-1} (Imai et al., 2002)

Ingestion of macrozooplankton composed 4-13% of primary production

Respiratory flux (mg C m^{-2} day^{-1})



Total: 4-19 mg C m^{-2} day^{-1}

Passive sediment flux at St. Knot (44°N, 155°E): 91 mg C m^{-2} day^{-1} (assuming *f*-ratio as 0.4)

Respiratory flux by macrozooplankton composed 4-21% of passive sinking flux

9: Discussion-comparison with other region

Location	Migrant Biomass (mg C m^{-2})	Component	Migratory flux (mg C m^{-2} day^{-1})	Compared with POC flux %	Depth (m)	Source
Atlantic Ocean						
BATS (31°50'N, 64°10'W)	191	Mesozooplankton	15	34	150	Dam et al. (1995)
BATS	49	Mesozooplankton	1.5	6	150	Steinberg et al. (2000)
Pacific Ocean						
Eastarn Equator (140°W)	96	Mesozooplankton	4.2	18	150	Zhang and Dam (1997)
Eastarn Equator	155	Mesozooplankton	7.3	25	150	Zhang and Dam (1997)
ALOHA (22°45'N, 158°W)	126	Meso- and macrozooplankton	3	18	150	Steinberg et al. (2008)
K2 (47°N, 160°E)	1280	Meso- and macrozooplankton	20	72	150	Steinberg et al. (2008)
K2	116	*Metridia pacifica*	3	10	150	Kobari et al. (2008)
St. 16	306	Amphipods+euphausiids	5.2 (2.2+3.0)	6	-	This study
St. 10	1096	Amphipods+euphausiids	18.7 (8.5+10.1)	21	-	This study
St. 2	280	Amphipods+euphausiids	4.2 (0.1+4.1)	4	-	This study

Migratory flux of macrozooplankton in this study is comparable to the other studies. Since this study evaluated only those of amphipods and euphausiids, total migratory flux would be more greater.

10: Summary

Community structure

Number of species: 17 genera 25 species (amphipods)

7 genera 19 species (euphausiids)

Dominant species varied between subtropial region and transition domain

DVM behavior was observed for:

***Cyphocaris challengeri, Themisto pacifica, Vibilia gibbosa* (amphipods) and**

***Euphausia* spp., *Thysanoessa* spp., *Nematoscelis* spp. (euphausiids)**

Carbon flux

Ingestion: 9-31 mg C m^{-2} day^{-1} (4-13% of primary production)

Respiration: 4-19 mg C m^{-2} day^{-1} (4-21% of passive sinking flux)

Contribution of active carbon flux by migratory macrozooplankton seems to be large