Article

Temporal Dynamics and Patterning of Meiofauna Community by Self-Organizing Artificial Neural Networks

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Abstract : The temporal dynamics of the meiofauna community in Marian Cove, King George Island were observed from January 22 to October 29 1996. Generally, 14 taxa of metazoan meiofauna were found. Nematodes were dominant comprising 90.12% of the community, harpacticoid 6.55%, and Kinorhynchs 1.54%. Meiofauna abundance increased monthly from January to May 1996, while varying in abundance after August 1996. Overall mean abundance of metazoan meiofauna was 2634 ind./10 cm^2 during the study periods, which is about as high as that found in temperate regions. Nematodes were most abundant representing 2399 ind./10 cm^2. Mean abundance of harpacticoids, including copepodite and nauplius was 131 ind./10 cm^2, followed by kinorhynchs (26 ind./10 cm^2). The overall abundance of other identified organisms was 31 ind./10 cm^2. Other organisms consisted of a total of 11 taxa including Ostracoda (6 ind./10 cm^2), Polycheata (7 ind./10 cm^2), Oligochaeta (8 ind./10 cm^2), and Bivalvia (6 ind./10 cm^2). Additionally, protozoan Foraminifera occurred at the study area with a mean abundance of 263 ind./10 cm^2. Foraminiferans were second in dominance to nematodes. The dominant taxa such as nematodes, harpacticoids, kinorhynchs and the other taxa were trained and extensively scattered in the map through the Kohonen network. The temporal pattern of the community composition was most affected by the abundance dynamics of kinorhynchs and harpacticoids. The neural network model also allowed for simulation of data that was missing during two months of inclement weather. The lowest meiofauna abundance was found in August 1996 during winter. The seasonal changes were likely caused by temperature and salinity changes as a result of meltwater runoff, and the physical impact by passing icebergs.

Key words : meiofauna, Antarctica, artificial neural network, temporal dynamics

1. Introduction

Meiofauna abundance is generally highest in the warm months of the year (Higgins and Thiel 1988), and abundance varies with several peaks. Although temperature is considered a primary factor controlling abundance fluctuations, a direct relationship between meiofauna and temperature is difficult to establish from field data. Many studies suggest other controlling factors, such as strong winds and irregular river discharges (Guidi-Guilvard and Buscail

1995), development time and reproductive strategy of the dominant species (Bouvy and Soyer 1989), and predation on meiofauna (Sibert 1979; Findlay 1981; Coull 1985; Smith and Coull 1987). These results are mainly from temporal regions. In contrast, little is known about meiofauna in polar regions (Pfannkuche and Thiel 1987; Szymelfenig et al. 1995; Herman and Dahms 1992). Moreover, due to difficulties of obtaining samples, there is no information on temporal variations of meiofauna communities in the subtidal zones of Antarctic coastal areas. There are reports on the intertidal meiofauna of Kerguelen Island (Bouvy and Soyer 1989) and on the deep sea meiofauna in the

Weddell Sea (Herman and Dahms 1992) near the present study area.

Recently, benthic communities in Maxwell Bay, which includes Marian Cove in King George Island, have been studied by the Korea Antarctic Research Program to produce an inventory of coastal biological resources (Ahn and Kang 1991; Choe *et al.* 1994). As part of this program, the present work aims at describing the temporal dynamics of meiofauna in the subtidal zone of Marian Cove, King George Island.

Community dynamics are complex and difficult to analyze since they consist of many species, varying in nonlinear fashion in spatio-temporal terms. There have been numerous accounts of statistical analyses on communities obtained through conventional multivariate analyses in ecology (Bunn *et al.* 1986; Legendre and Legendre 1987; Ludwig and Reynolds 1988; Quinn *et al.* 1991). Classification and association of communities have been studied by multivariate statistical analyses such as measuring distance among sampled communities and taxa (Legendre and Legendre 1983; Ludwig and Reynolds 1988). However, multivariate methods are limited in the sense that they are mainly applicable to linear data (Ludwig and Reynolds 1988) and have less flexibility in representing ecological data, as in the case of data handling or missing samples.

Recently, modern information-extraction methods in machine intelligence such as artificial neural networks (ANNs) have drawn attention as an alternative tool to pattern complex ecological data. Artificial neural networks are parallel and distributed information extraction processors, have adaptive and self-organizing properties, and are consequently feasible in handling nonlinear data. In ecological studies, ANNs have been applied in many respects such as classifying groups (e.g., Chon *et al.* 1996; Levine *et al.* 1996; Chon *et al.* 2000a; Kwak *et al.* 2000), patterning complex relationships (e.g., Huntingford and Cox 1996; Lek *et al.* 1996; Tuma *et al.* 1996) and predicting population and community dynamics (Elizondo *et al.* 1994; Tan and Smeins 1996; Recknagel *et al.* 1997; Stankovski *et al.* 1998; Chon *et al.* 2000b, 2000c, 2001a, 2001b). In this study, we implemented self-organizational mapping (SOM) and the complex data of communities were further classified in groupings of communities and taxa.

2. Materials and methods

Study area
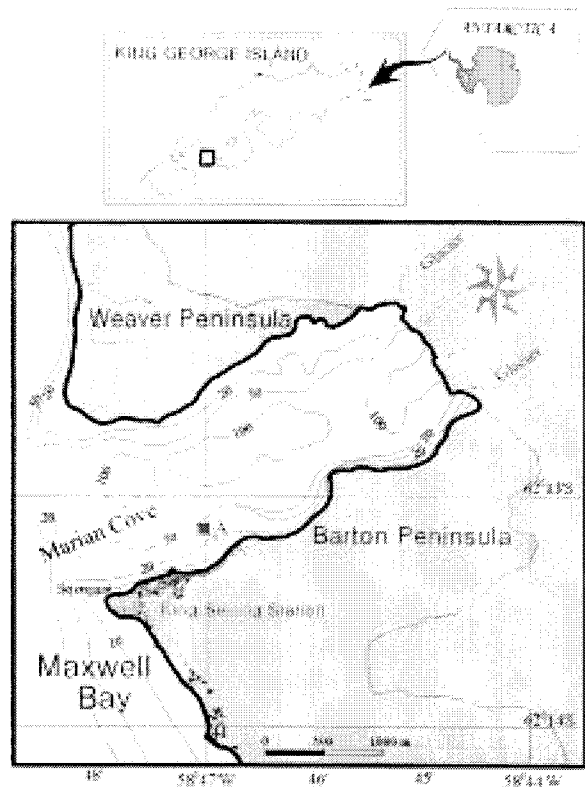During the period of December 1995-January 1996,

Fig. 1. Study area (A, sampling site).

bottom sediment was sampled and analyzed to investigate the seasonal abundance of meiofauna in Marian Cove (Fig. 1). Marian Cove is one of the glacial-eroded fjords along the southern margin of the South Shetland Islands, West Antarctica. Marian Cove is bounded by the Weaver Peninsula to the northwest and the Barton Peninsula to the southeast, and is bathymetrically separated from Maxwell Bay by a shallow (less than 20 m) submarine sill at the mouth. Small valley glaciers, draining southwest from the cove heads, discharge a large amount of icebergs and turbid melted water into the cove during the summer months. Meltwater streams are common on the coast, forming a small outwash fan. Large-sized rocks and gravel form the basement and no sand and mud occur at the intertidal zone near sampling stations. The rocks and gravel expand to depths of 15-20 m and may block the formation of meiofauna communities in the intertidal and subtidal zones. Very fine mud forms the bottom sediment in more than 80% of the upper 90 cm layer in the subtidal zone of Marian Cove, because small turbid particles from glaciers settle at the bottom (Hong *et al.* 1991).

Normally, the sea ice formed more than 10-20 cm thickness during the winter season in Marian Cove.

However, sea ice formed just transiently during the study periods due to warmer temperatures and stronger winds than in previous years. Large-sized floating icebergs driven by strong winds floated into Marian Cove, occasionally. Sometimes, these floating icebergs would become grounded near a sampling station for one or two days.

Sampling and laboratory procedures

Sampling stations were located in front of the King Sejong Station, Korea Antarctic base (62°13'244"S, 58°47'034"E). Bottom sediment was sampled over 1 or 2 week intervals, from January 22 to October 29 1996. Samplings were divided into two phases during periods extending from January 22 to May 14 and from August 7 to October 29. Sampling was not made during June and July 1996, due to inclement weather conditions. Samplings were undertaken on a Zodiac rubber boat. The water depths ranged from 30-40 m. Bottom sediment was extracted using a free-fall corer that had an internal acrylic tube (internal area; 1.934 cm², length 20 cm) and a small stainless steel ball as a cap. To minimize disturbance of the surface layer of each sample, the velocity of the corer was reduced before it hit bottom. Sediment was sampled to a depth of 10 cm. Usually, six replica cores were taken. Cores were carried to the laboratory to undergo an extraction process.

To identify each taxon, four cores of each sample were placed in separate 125 m*l* bottles. All cores were processed separately. Sediment in each bottle was preserved in 5% formalin and stained with Rose Bengal. After sieving with two meshes (1 mm and 38 μm mesh size), the animals retained on the 38 μm sieve were observed under a low-powered stereomicroscope to sort the animals. Sorted animals were counted in a grid plastic Petri dish for each taxon. The data were converted to abundance (individuals per 10 cm²).

The remaining two cores were used to analyze TOM (Total Organic Matter) and humidity. Sediment from the two cores was dried at 60°C (24 hr) to remove humidity and then incinerated at 550°C (6 hr) for TOM. Samples were weighed on a Mettler ultra balance with 1 μg accuracy.

Other environmental factors, such as water temperature, salinity, chlorophyll a (Chl a), and particulate matter in the water column were surveyed using a CTD. Wind speed and air temperature were obtained from the 9th KARP over-winter report (KORDI 1997).

Artificial neural networks

The first step is to use Kohonen self-organized mapping
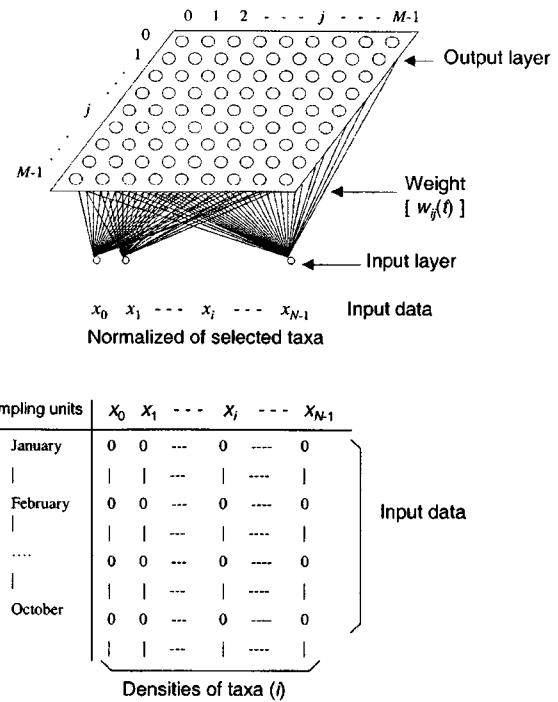
Fig. 2. Architecture of the Kohonen network (Adapted from Chon *et al.* 1996).

(SOM) on input data to classify community composition. The Kohonen network is supposed to have a linear array of M^2 output neurons (i.e., computation nodes) with each neuron being represented as j (Fig. 2). The input vector x is an input layer for the Kohonen network, and meiofauna communities for a certain period are provided as input to the network. In the network, each neuron at the output layer, j, is supposed to be connected to each node, i, of the input layer. The connectivity is represented as weight, $w_{ij}(t)$, adaptively changing at each iteration of calculations, t. Initially, the weights are randomly assigned in small values. Each neuron of the network calculates the summed output distance between the weight and input as shown below:

$$d_j(t) = \sum_{i=0}^{N-1} (x_i - w_{ij}(t))^2$$

The neuron responding maximally to a given input vector is selected as the winning neuron, the weight vector of which has the shortest distance to the input vector. The winning neuron and possibly its neighboring neurons are allowed to learn by changing its weight to further reduce the distance between the weight and the input vector as shown below:

$$w_{ij}(t+1) = w_{ij}(t) + \eta(t)(x_i - w_{ij}(t))Z_j$$

where Z_j is assigned 1 for the winning (and its neigh-
boring) neuron(s), while being assigned 0 for the other
neurons, and $\eta(t)$ (e.g., 0.1-0.4) denotes the fractional
increment of the correction. The radius definition neigh-
borhood is usually set at a larger value early in the train-
ing process, and is gradually decreased as convergence is
reached. Detailed algorithms are given in Lippmann (1987),
Kohonen (1989), Hecht-Nielsen (1990), Zurada (1992) and
Chon et al. (1996).

Statistical analysis

A multivariate analysis was used to examine relationships
between community structure and environment. The relative
abundance of selected taxa in the community and environ-
ment was analyzed by using principle component analysis
(PCA). Physical habitat, air temperature, water tempera-
ture, chlorophyll a, UV-b, TOM, salinity, wind and
particulate materials, and animal taxa abundance were
log-transformed as $\ln(x + 1)$. All analyses were carried out
using ADE4 software, a package for multivariate analysis
for environmental data, which is available on the Internet
at: http://biomserv.univ-lyon1.fr.ADE-4.html.

3. Results

Environmental characteristics

Monthly mean water temperature ranged from 1.64 to
−1.68°C. Water temperatures were above 0°C until April,
and below 0°C from May to October 1996 (Fig. 3a).
Salinity fluctuated with a range from 31.37 to 34.98 PSU.
Salinity was very low until March 1996 due to the
meltwater from glaciers and land, but very high during the
winter months (Fig. 3c). Chl a ranged from 0.3 to 2.81 $\mu g/l$
(Fig. 3b). UV-b values ranged from 0.009316 to 0.0457
med/hr. The range of particulate matter in the water
column was from 26.03 to 31.41 mg/l (Fig. 3d). The
particulate matter correlated with the temperature because
it originated mostly from glaciers. Monthly mean air
temperature ranged from 2.9 to −6.2°C during the study
period (Fig. 3a). Monthly mean wind speed ranged from
6.3 to 10.5 m/s (Fig. 3d). Mean humidity was 40.15%.
Mean TOM was 4.05% with a range of 3.13 to 4.83%.
Sediment grain size fractions were comprised of coarse
sand, fine sand, and silt and clay were 3.31%, 68.27%,
and 28.42% respectively.

Community composition of the meiofauna

Overall mean abundance of metazoan meiofauna was
2634 ind./10 cm² during the study period (Table 1).
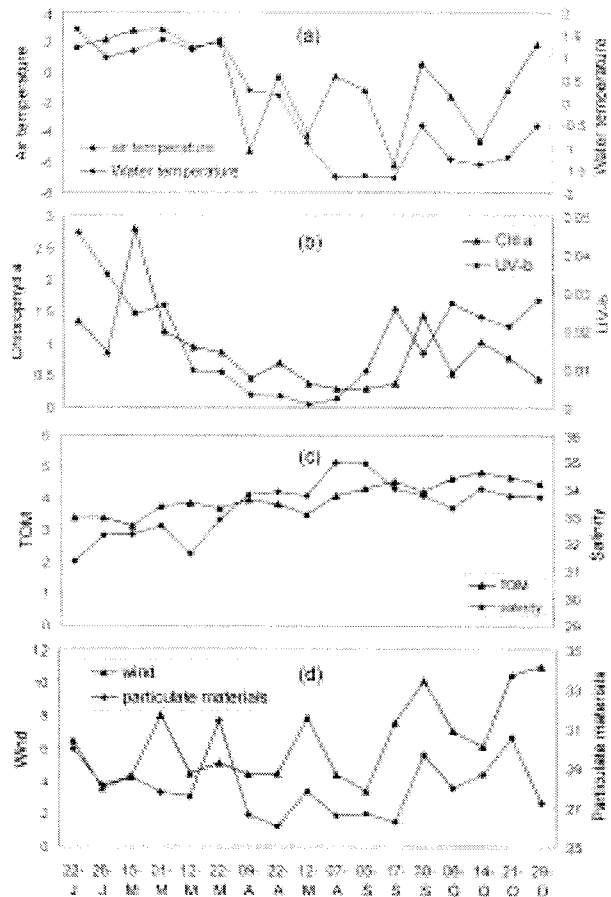
Fig. 3. Environmental factors: (a) air temperature and
water temperature, (b) chlorophyll a (Chl a) and
UV-b, (c) total organic matter (TOM) and salin-
ity and (d) wind and particulate materials of
study site in Marian Cove, King George Island,
Antarctica.

Nematodes were most abundant representing 2399 ind./
10 cm². Mean abundance of harpacticoids, including
copepodites and nauplii, was 131 ind./10 cm², followed by
kinorhynchs (26 ind./10 cm²). The overall abundance of
other organisms was 31 ind./10 cm². Other organisms
consisted of a total of 11 small taxa, including ostracodes
(6 ind./10 cm²), polycheates (7 ind./10 cm²), oligochaetes
(8 ind./10 cm²), and bivalves (6 ind./10 cm²). Additionally,
protozoan foraminiferans occurred in the study area with
a mean abundance of 263 ind./10 cm².

The mean composition of nematodes was 90.21%, and
harpacticoids comprised 6.55% of the community.
Kinorhynchs comprised 1.54% of the community. Densities
increased from January to May and from August to
December during study periods except for several decreased

Table 1. Abundances of meiofauna during the study periods (number of individuals/10 cm²).

	22-Jan	26-Jan	15-Feb	1-Mar	12-Mar	22-Mar	9-Apr	22-Apr	14-May	7-Aug	5-Sep	17-Sep	30-Sep	6-Oct	14-Oct	21-Oct	29-Oct	Mean
Protozoan																		
Foraminifera	44	346	173	771	429	673	946	209	15	103	25	54	133	164	102	26	257	263.00
Tintinnida	0	1	0	1	0	0	5	0	0	0	1	0	0	0	0	0	0	0.54
subtotal	44	347	173	773	429	673	951	209	15	103	26	54	133	164	102	26	257	263.54
Metazoan																		
Cnidaria	44	3	0	1	0	1	0	0	0	0	0	0	0	1	1	0	0	3.04
Kinorhyncha	0	0	0	8	21	4	9	10	62	19	72	40	9	97	16	10	70	26.29
Harpacticoida	18	50	38	121	25	49	134	36	72	45	71	50	32	83	32	53	62	57.22
Nauplius	8	16	39	128	43	41	173	47	101	39	49	50	47	123	72	62	214	73.58
Poecilostomatoida	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.45
Amphipoda	0	3	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0.37
Cumacea	5	3	4	4	0	0	1	0	0	0	1	0	0	3	0	0	0	1.21
Ostracoda	8	0	4	10	7	7	13	0	8	1	18	9	1	3	3	6	10	6.32
Tanaidacea	0	0	4	1	1	0	0	0	0	0	1	4	3	0	1	0	0	0.91
Isopoda	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0.15
Nematoda	494	1101	1792	3988	1518	4547	3557	2359	7982	418	960	1561	1190	1955	2526	957	3886	2399.46
Polychaeta	16	7	30	4	0	10	14	3	0	12	0	0	7	3	3	4	5	6.75
Oligochaeta	13	0	47	12	3	8	14	5	0	0	0	1	1	1	8	5	10	7.52
Bivalvia	0	7	36	35	1	14	8	0	3	1	0	0	0	0	0	0	0	6.16
Gastropoda	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0.31
Puliapulida	0	0	0	0	0	0	0	0	5	0	0	1	0	0	0	3	0	0.54
Unknown Organism	54	0	94	41	31	4	7	47	3	3	17	7	8	10	40	8	127	29.33
Unknown Egg	0	22	114	16	3	13	7	0	0	1	0	1	0	0	18	27	23	14.37
Egg Sac	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15
subtotal	667	1212	2200	4377	1651	4698	3937	2507	8235	539	1193	1725	1297	2278	2721	1136	4408	2634.14
TOTAL	711	1559	2373	5150	2080	5371	4888	2716	8250	642	1219	1779	1430	2442	2823	1162	4665	2897.68

values (Fig. 4). The highest abundance was 8235 ind./10 cm² on May 14, while the lowest abundance was 539 ind. /10 cm² on August 7. Nematodes ranged from 78.04% on August 7 to 97.16% on May 14. The abundance of nematodes strongly influenced the total meiofauna abundance.

The abundance of harpacticoids varied widely during the study period with six peaks. Mean abundance was 57 ind./10 cm² including adults and copepodites with a range of 134 ind./10 cm² on April 9 to 18 ind./10 cm² on January 22. The mean abundance of nauplius stages was 74 ind./10 cm² with a range of 214 ind./10 cm² on October 29 to 8 ind./10 cm² on January 22.

Kinorhynchs were the only other taxa that were more than 1% of total meiofauna abundance. The mean abundance of kinorhynchs was 26 ind./10 cm². Kinorhynchs occurred during the whole study period, except for

January and February 1996.

Mean nematodes: copepods ratio (N/C) ranged from 8 to 50 and the overall mean was 18. Although N/C ratios were very high on March 22 (50) and May 14 (46), there were no significant trends in their values during the study period.

Patterning using the Kohonen network

The dynamics of the other taxa (i.e., the remaining taxa) were different from kinorhynchs, nematodes and harpacticoids. The abundance of dominant families was high, but the other taxa were low in the study site. The correlation coefficient between the other taxa and dominant families was relatively low ranging from −0.255 to 0.055 (F-value 1.020-1.685) and not significant, the correlation between nematodes and harpacticoids was 0.525 (F-value 3.214), which is significant. The nematodes and kinorhynchs
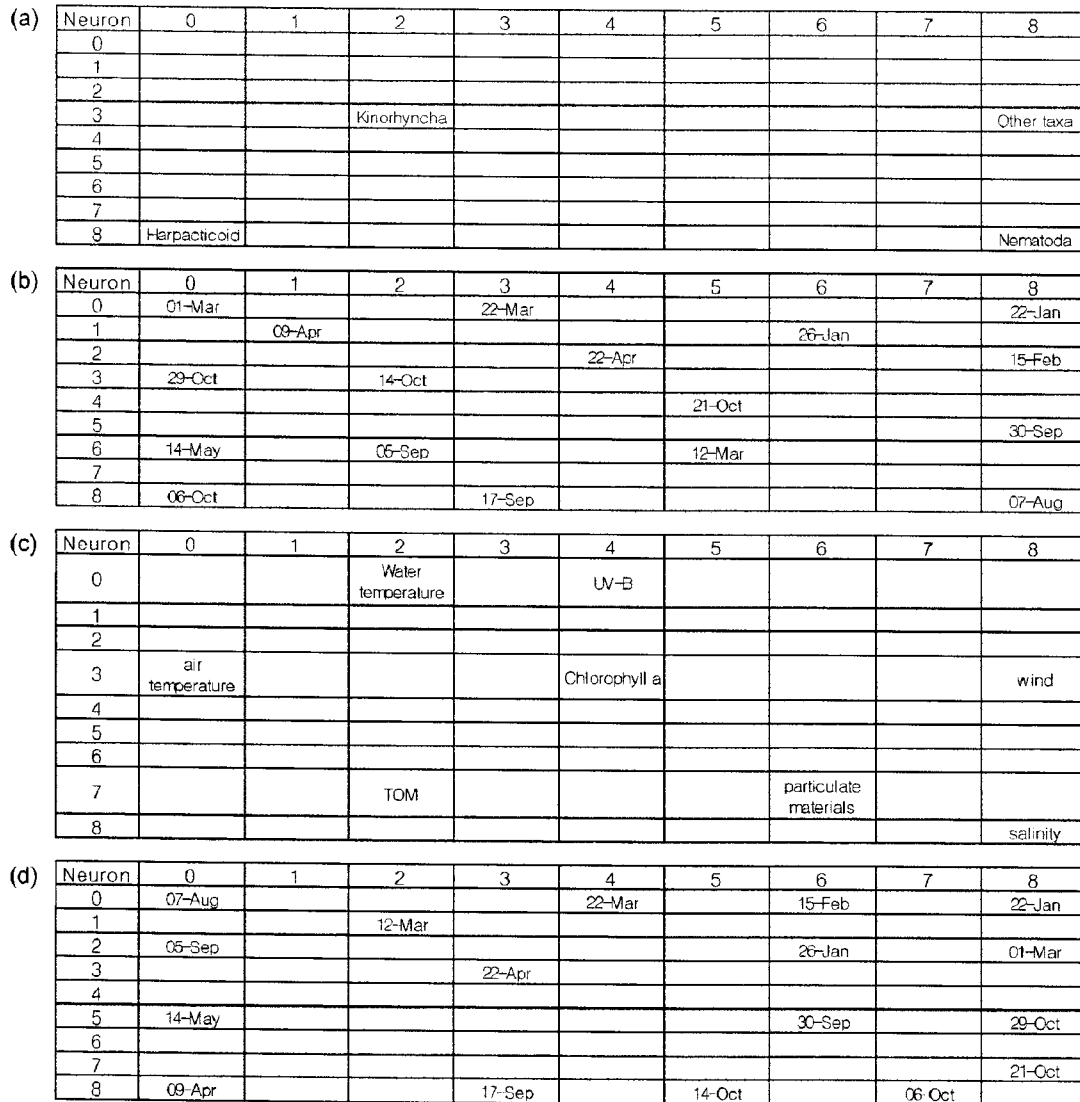
Fig. 4. Community dynamics: (a) Nematoda, (b) Harpacti-coids, (c) Kinorhyncha and (d) other taxa of study site in Marian Cove, King George Island, Antarctica.

correlation was 0.236 (F-value 1.618), and the correlation of kinorhynchs and harpacticoids was 0.420 (F-value 2.450) (Table 2).

Generally, the groups were widely scattered on the Kohonen map through the relationships between community dynamics of organisms and environmental factors (Fig. 5). The Kohonen network effectively presents characteristics of the community composition, dynamics involving monthly abundance changes of meiofauna, environmental factors, and dynamics involving environmental factors. The dominant taxa such as nematodes, harpacticoids, kinorhynchs and other taxa were extensively scattered throughout the map of the Kohonen network (Fig. 5a). The temporal community abundance dynamics of kinorhynchs and harpacticoids shows that the abundance of harpacticoids decreased from the left region to the right region of the map (Fig. 5b). In contrast, kinorhynchs increased from the upper region to the lower region in the Kohonen map. Therefore, the temporal domain showed increasing abundance of harpacticoids, while the kinorhynchs showed a decrease.

For environmental factors, the correlation coefficients

Table 2. The correlation coefficients appeared in relationships involving 8 environmental factors and selected taxa in this study. $F_{0.05}(2), 15, 15=2.86$

		TOM	Chl a	UV-B	Water temperature	Salinity	Air temperature	Wind	Particulate materials	Nema-toda	Harpac-ticoid	Kino-rhyncha	Other taxa
TOM	r^2	1.000	−0.487	−0.010	−0.765	0.592	−0.502	0.449	−0.107	−0.195	0.259	0.471	−0.420
	F-value		2.901	1.020	7.524	3.905	3.018	2.633	1.240	1.483	1.699	2.782	2.448
Chl a	r^2		1.000	0.365	0.553	−0.562	0.508	−0.058	0.417	−0.185	−0.342	−0.527	0.766
	F-value			2.149	3.476	3.570	3.068	1.122	2.431	1.454	2.041	3.232	7.560
UV-B	r^2			1.000	0.276	−0.543	0.307	−0.058	0.326	−0.354	−0.137	−0.080	0.415
	F-value				1.762	3.378	1.887	1.122	1.968	2.095	1.317	1.173	2.421
Water temperature	r^2				1.000	−0.575	0.503	−0.061	0.380	0.088	−0.127	−0.595	0.480
	F-value					3.702	3.021	1.129	2.227	1.194	1.291	3.941	2.844
Salinity	r^2					1.000	−0.563	0.089	−0.423	0.042	0.245	0.396	−0.423
	F-value						3.575	1.194	2.464	1.087	1.648	2.312	2.466
Air temperature	r^2						1.000	−0.048	0.349	−0.205	−0.241	−0.315	0.474
	F-value							1.101	2.072	1.515	1.635	1.921	2.804
Wind	r^2							1.000	0.304	0.208	0.315	0.227	−0.009
	F-value								1.875	1.525	1.921	1.586	1.017
Particulate materials	r^2								1.000	0.001	−0.324	−0.364	0.132
	F-value									1.001	1.957	2.142	1.303
Nematoda	r^2									1.000	0.525	0.236	−0.010
	F-value										3.214	1.618	1.020
Harpacticoid	r^2										1.000	0.420	0.055
	F-value											2.450	1.116
Kinorhyncha	r^2											1.000	−0.255
	F-value												1.685
Other taxa	r^2												1.000
	F-value												

(a)

Neuron	0	1	2	3	4	5	6	7	8
0									
1									
2									
3			Kinorhyncha						Other taxa
4									
5									
6									
7									
8	Harpacticoid								Nematoda

(b)

Neuron	0	1	2	3	4	5	6	7	8
0	01-Mar			22-Mar					22-Jan
1		09-Apr					26-Jan		
2					22-Apr				15-Feb
3	29-Oct		14-Oct						
4							21-Oct		
5									30-Sep
6	14-May		06-Sep				12-Mar		
7									
8	06-Oct			17-Sep					07-Aug

(c)

Neuron	0	1	2	3	4	5	6	7	8
0			Water temperature		UV-B				
1									
2									
3	air temperature				Chlorophyll a				wind
4									
5									
6									
7			TOM				particulate materials		
8									salinity

(d)

Neuron	0	1	2	3	4	5	6	7	8
0	07-Aug				22-Mar		15-Feb		22-Jan
1			12-Mar						
2	05-Sep						26-Jan		01-Mar
3				22-Apr					
4									
5	14-May						30-Sep		29-Oct
6									
7									21-Oct
8	09-Apr			17-Sep		14-Oct		06-Oct	

Fig. 5. The map trained by the Kohonen network for patterning: (a) meiofauna (Q-mode) and sampling, (b) sampling date (R-mode), (c) environmental factors (Q-mode) and (d) sampling date (R-mode) in study site in Marian Cove, King George Island, Antarctica.

were higher than for organisms (Table 2). Salinity and TOM had a significant F-value for all environmental factors except wind. The patterning of the eight environmental factors in the monthly temporal domain appeared widely scattered on the Kohonen map (Fig. 5c). The patterning of survey dates shows the period from March through August on the left and September through January on the right. Consequent succession is observed in temperature and salinity (Fig. 5d). TOM and chlorophyll a contributed a great deal to the distribution of environmental factors on the map because TOM increased in the upper to lower regions, while chlorophyll a decreased from the upper to lower regions on the map (Fig. 5d).

Principal environmental factors

A PCA was conducted on environmental factors (Fig. 6). The first axis was the most important, accounting for 50.40% of the total variability of data (Eigenvalue 11.379) and the second axis accounted for 34.78% of the variability (Eigenvalue 7.851). Certain factors were strongly associated. The first axis separated chlorophyll a and water temperature from wind, TOM And salinity. This is similar to the pattern found in the Kohonen network, where TOM and salinity had significant correlation coefficients.
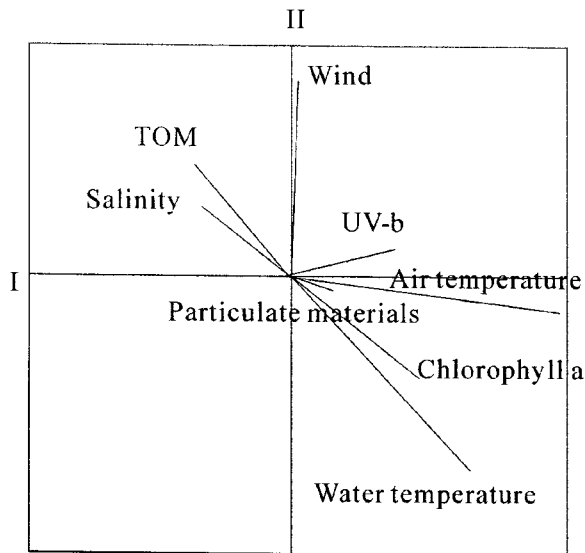
Fig. 6. Principal Component Analysis (PCA) showed ordination 8 environmental factors (I: factor I, II: factor II and TOM: total organic matter).

4. Discussion

Abundance of meiofauna in Marian Cove during the present study was very high, and similar to those from the tropical and temporal regions. Overall mean abundance of metazoan meiofauna was 2634 ind./10 cm^2 over the study period. The overall abundance of meiofauna in the present study is similar to those from Hally Bay in the eastern Weddell Sea (Herman and Dahms 1992) and higher than in Svalbard Island in the Arctic (Szymelfenig et al. 1995). There are few reports on the seasonal variations of meiofauna communities in the Antarctic or SubAntarctic region. Bouvy and Soyer (1989) reported that there were no seasonal trends in the abundance of meiofauna with seven peaks at the intertidal zone around Kerguelen Island. In temperate regions, meiofauna abundance tends to roughly follow a seasonal pattern. For example, in the northwestern Mediterranean meiofauna are marked by high values in autumn, decreases in winter and increases again in summer (Guidi-Guilvard and Buscail 1995). Generally, meiofauna has its highest abundance in the warmer season (Higgins and Thiel 1988), while abundance decreases in summer in some areas due to other environmental factors such as low dissolved oxygen, and prey resources (Guellec and Bodin 1992; Huys et al. 1986; Coull and Wells 1981). Meiofauna increased from January to May and August to October and had peaks during cold periods in Marian Cove, which was similar to

the report from Kerguelen Island by Bouvy and Soyer (1989).

The total abundance of meiofauna depended on the abundance of nematodes. The nematodes did not significantly correlate with environmental factors such as TOM, Chl a, water temperature, salinity, and particulate matter. A significant correlation between meiofauna and potential food sources such as Chl a and bacteria were reported in many regions (Alongi and Pichon 1988; Coull and Dudley 1985; Pfannkuche 1985; Palacin et al. 1992; Tietjen et al. 1989). Meiofauna taxa may have different feeding responses to changes in production of microphytobenthos. Nematodes apparently respond to increased benthic primary production with increased grazing rates, but the crustacean groups (harpacticoids and ostracods) did not change their feeding rates (Montagna et al. 1995). At Kerguelen Island, significant seasonal correlations were found between temperature, organic matter parameters, bacterial abundance and biomass, and daily primary production, but no correlations were found between the physical factors measured and the meiofauna (Bouvy and Soyer 1989). Unfortunately, bacterial abundance and biomass were not measured in the present study.

Sea ice conditions are also an important factor influencing meiofauna. Generally, thick sea-ice forms in Marian Cove during winter. These icebergs may interfere with primary productivity by lowering light intensity and water temperature during winter. However, sea ice did not form during the study period, because this particular year was relatively warm. Therefore, this study period may be unusual, and the results reported here may not represent a typical annual trend.

During the warmer months, meltwater inflow obviously affects temperature and salinity in Marian cove, and temperature and salinity were significantly different between the summer and winter months. This massive inflow of meltwater could affect the abundance of meiofauna, since each meiofaunal species has an optimal range for salinity and temperature. In tropical regions, community structure and seasonality of meiofaunal copepods are influenced by monsoons that bring about dynamic changes in temperature and salinity in estuaries and coastal waters (Ansari and Parulekar 1993). Thus, both the polar and tropical regions seem to be affected by freshwater inflow to the coast.

The other factor that affects abundance of meiofauna are the likely physical impacts of floating icebergs. Among the sampling dates, March 12, April 22 and October 21, there was a decreased abundance that coincided with the time when floating icebergs passed near a sampling station.

The depth at the sampling station was relatively shallow (30-40 m) and there was possibly mechanical disturbance of the bottom sediments by the large icebergs. These decreased abundances of meiofauna recovered very fast after 10, 22 and 8 days, respectively.

In addition to the abundance of nematode, the harpacticoid abundance correlated to that of the total meiofauna. The abundance of nauplii larvae was as high as those for adults. This suggests that reproduction of harpacticoids was active during the winter season in Marian Cove. Although breeding activity of harpacticoids was higher during the warmer season along the North Sea coast (Huys *et al.* 1986), some harpacticoids showing continual breeding throughout the year (Hicks 1984).

The factors that could affect the abundance of meiofauna were physical factors (temperature, salinity and wind speed), biological factors (Chl a, TOM, Bacteria) and mechanical disturbances by icebergs. However, meiofauna did not correlate to environmental factors directly. Although the disturbance of bottom sediment by strong winds can cause fluctuations in the abundance of meiofauna, there was no relationship between meiofauna and environmental factors in the present study. The intervals between each sampling were irregular and long, about one month. Recolonization of disturbed sediment in temperate regions can be rapid, occurring over a period of less than one month (Palmer 1988; Sherman and Coull 1980). But in the polar region, there is no data to suggest that the time interval used in this study is too short to predict temporal change.

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