Geographical and biological characteristics of the net zooplankton in the southwestern part of the Sea of Okhotsk during 1987–1996

Irina Y. BRAGINA

Sakhalin Research Institute of Fisheries and Oceanography, Yuzhno-Sakhalinsk, Russia

Abstract

During 1987–1996 zooplankton studies were conducted by standard stations in the neritic, shelf and continental slope zones in the southwestern part of the Okhotsk Sea. Zooplankton species were collected by Juday net by total catch from 100 m up to the surface. The comparative zooplankton species analysis included 88 forms from 5 subareas and one transect that covered different geographical conditions. Defined: (1) species determination, biomass dynamics, distribution and possible driving environmental factors of the net zooplankton biomass, (2) zooplankton ecological characteristics, (3) taxonomic group predominance in biomass (*Chaetognatha, Euphausiidae, Copepoda*) and (4) proportion of the predator/prey ratio. Regions were determined where conditions for the fish feeding was estimated as the richest. Level biomass range varied from 203–2055 mg/m^3. The most productive area has been estimated to be east off Terpenia Peninsula. The role of *Chaetognatha* predominance (up to 75% in plankton biomass) was determined as negative in feeding accessibility as well for the fish juvenile survival. The high zooplankton biomass level corresponded to low-temperature years.

Introduction

Structure and zooplankton community dynamics are the factors influencing fish concentrations such as herring, walleye pollock, atka mackerel, and juvenile salmon, which are critically important for the Sakhalin fishery industry. Relations between zooplankton community conditions and reproduction, quantity and distribution of pelagic fishes that inhabit the southwestern part of the Sea of Okhotsk are well investigated (Kun 1951, 1975, 1985; Mikulich, 1957; Lubny-Gercik, 1962; Guryeva, 1973; Shvetsova and Budaeva 1975; Fedotova, 1978a, 1978b, 1980, 1992; Chuchukalo, 1988; Bragina and Fedotova 1990, 1991; Bragina 1989, 1992, 1994, 1997; Gorbatenko, 1990; Volkov et al., 1990; Seki et al., 1995; Fedotova and Hudya 1995; Afanasyev, 1981; Shuntov and Dulepova 1996; Samatov 1994, 1995).2.

During the last decade, climatic fluctuations in the Northern Pacific had an impact, particularly on the Sea of Okhotsk oceanographic regime. Principally, the investigation of marine ecosystem response to that impact is the prime goal of numerous studies conducted here by national and international institutes and organizations, including PICES. Net zooplankton were collected by the Sakhalin Research Institute of Fisheries and Oceanography (SakhNIRO) around Sakhalin on standard grid stations from 1987 to 1996. The goal of this paper is to describe the seasonal and interannual changes in the zooplankton community from the southwestern part of the Sea of Okhotsk during this period.

Data and Methods

Zooplankton grid stations are shown in Figure 1. Zooplankton were sampled by Juday net (net mouth area 0.1 m^2, mesh size 0.112 mm) from 100 m depth or from bottom to the surface. Plankters were fixed by 4% formalin on board ship and analyzed in the laboratory on land (Volkov et al., 1980; Volkov, 1984). Analysis consisted of two steps: species determination (Brodsky, 1950; Lomakina, 1978; Kasatkina, 1982; Gurjanova, 1951; Zevina, 1981; Stepanyants, 1967; Naumov, 1960, 1961; Kryuchkova, 1987) and biomass calculations (Lubny-Gercic, 1953; Chislenko, 1968). Total number of samples analyzed were 1480.

Geographical division of the southwestern part of the Sea of Okhotsk is based on bay borders (Aniva, Terpeniya), the deepest part of the Sea of Okhotsk, the wide northeastern shelf and slope off Sakhalin, south of 50°30′N latitude. Hence, 5 regions in the southwestern part of the Sea of Okhotsk with different geographical conditions are presented for the net zooplankton dynamics investigation. The line between Sakhalin and Kunashir

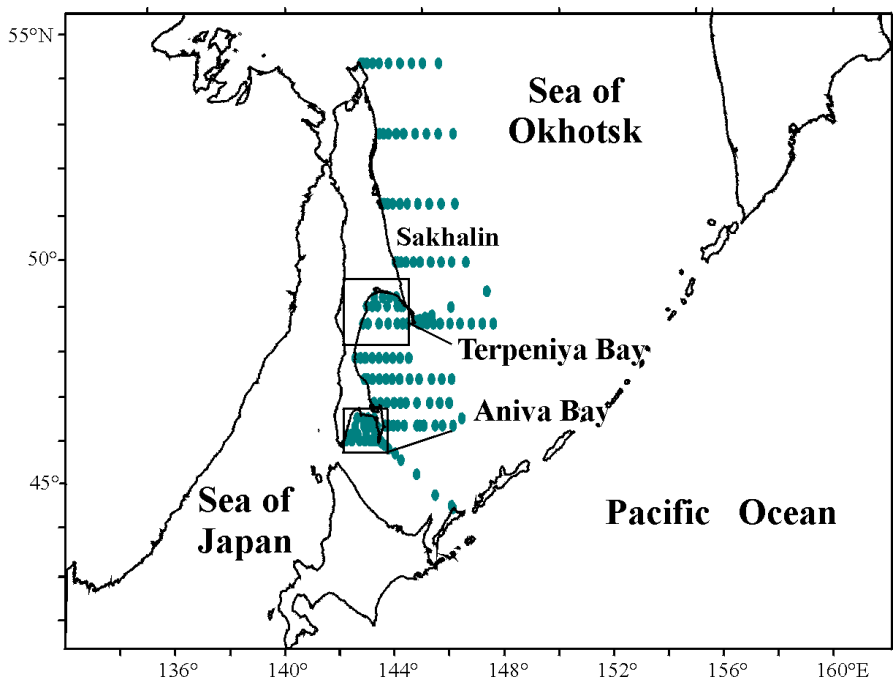

Fig. 1 Standard SakhNIRO grid sampling stations in the southwestern part of the Sea of Okhotsk, including Terpeniya and Aniva bays.

islands had a specific zooplankton composition and showed independence from other regions due to the influence of warm and saline waters of the Soya and West Sakhalin currents (Kantakov and Shevchenko, 1999).

In each region three biological parameters of the net zooplankton community were examined seasonally and interannually: total biomass (mg/m^3), ecological zooplankton group (i.e. species with similar temperature optimums) compositions, having main contributions in the net biomass (Kun, 1975). The third parameter was choosen as a ratio carnivore/omnivore (Omori and Ikeda, 1984) species of the net zooplankton.

Results

Species determination, biomass dynamics, distribution and possible environmental driving factors

Net zooplankton fauna were represented by a total of 88 forms belonging to the 9 types and 15 classes. More diversity was obtained for the *Copepoda* and *Euphausiacea* taxons. In biomass three plankter groups predominated: *Copepoda*, *Euphausiacea*, and *Chaetognatha*. A short species list is given in Appendix I.

In the spring macroplankton (2–20 mm) cold water species *Thysanoessa raschii*, *Parasagitta elegans*, and *Metridia okhotensis* formed most (68–86%) of the net zooplankton biomass (just biomass in following). In the fall period mezoplankton increased due to growth in biomass of *Pseudocalanus minutus*, *Centropages abdominalis*, the early stages of copepod coarse forms such as Fam. *Calanidae*, as well as the plankton stages of the benthos. The maximum (54–74%) of the mezoplankton part in biomass was found in the bays. The microplankton fraction (*Oithona similis*, copepods, eggs and nauplius of Copepoda, and larvae of benthic animals) composed both in spring and fall from 3 to 20 % of the biomass, but prevailed in quantity.

Biomass dynamics seasonally and interannually are shown in Figure 2. A remarkable feature of the biomass dynamics was minimum expression in the 1991 in all detached regions. The ranges of seasonal and interannual variabilities were close to each other (see Figure 2).

In spring biomass by regions varied from 216 to 2055 mg/m^3. The highest biomass was obtained in the bays and for region located south of 50°30′N. (See Figure 2A, D, and E and, as an example of the net zooplankton distribution, Figure 3) The poorest biomass measurement was for the northeastern offshore (north of 50°30′N; see Figure 2F).

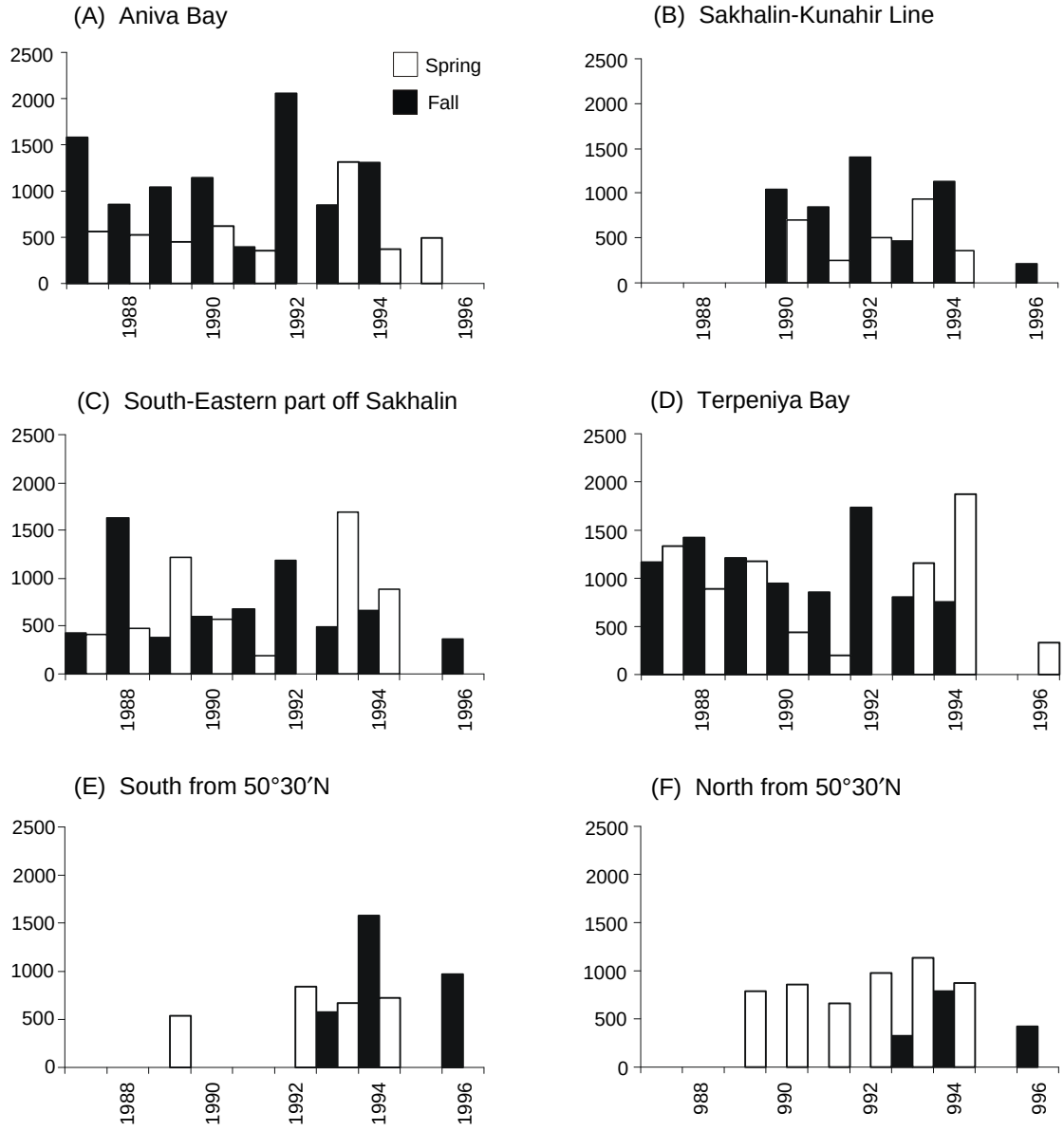

Fig. 2 Biomass (mg/m^3) dynamics by region and the Sakhalin–Kunashir line during the 1987–1996 period.

In the fall biomass ranged from 203–1871 mg/m^3. Meanwhile, in the deepest region southeast of Sakhalin and on the northeastern shelf, the biomass reached values higher than that for spring (Fig. 2 C and F).

In the Aniva and Terpeniya bays, biomass maximums registered in 1992 when environmental conditions were characterized by the smallest area of the Sea of Okhotsk ice cover, the East Sakhalin current relaxation and poor solar heating (Kantakov, 1993). The environmental factors indicate a possible impact (Kantakov, personal communication) of the numerous oceanological parameters on the zooplankton biomass as well species structure (see Table 1).

Ecology

Cold water species (CWS) were determinated to be less than 50% of the forms from total species list, but they prevailed in biomass in the spring and

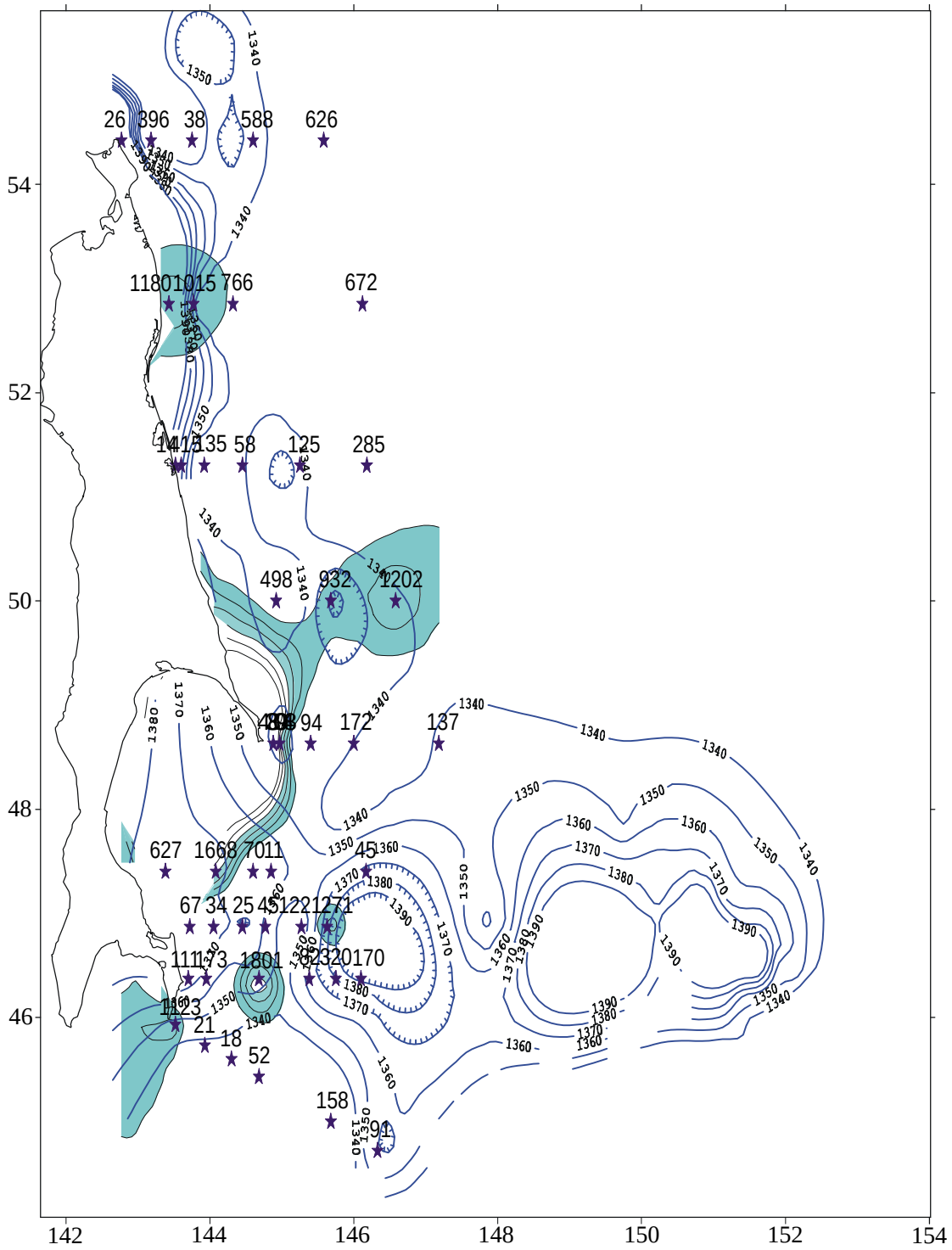

Fig. 3 Net zooplankton biomass (mg/m^3) and dynamic heights (ref.level 10/1000 db) distribution in June–July, 1996 (POI-SakhNIRO cooperative expedition at R/V *Gagarinsky*). Stars denote zooplankton stations, bold lines are lines of the dynamic heights, shaded area shows where biomass is more than 800 mg/m^3.

Table 1 Correlation between environmental and net zooplankton factors in spring time for Aniva Bay (data raw 1988–1994).

	BM	Cop	Efz	Chaet	Amph	Pred	Prey
BM	1.00						
Cop		1.00					
Efz	0.73		1.00				
Chaet	–0.60	–0.76	–0.34	1.00			
Amph	0.59		0.50		1.00		
Pred	–0.58	–0.87		0.96		1.00	
Prey	0.59	0.87		–0.97		–1.00	1.00
T50					–0.61		
T50_100	–0.98		–0.56		–0.81	0.51	–0.52
A50							
A50_100	–0.75				–0.86		
< 32	–0.63		–0.63	0.84		0.65	–0.69
32–33	0.90		0.69	–0.75		–0.62	0.66
33–34				–0.53	–0.51		
> 2			–0.92				
0–2	0.94		0.81	–0.67		–0.66	0.66
–2–0		–0.52	0.79				
N	–0.94		–0.80	0.56	–0.68		
S			0.74				
T	–0.77				–0.67		

Remarks: BM – biomass (mg/m^3), Cop – copepod biomass, Efz – *Euphausiidae* biomass, Chaet – *Chaetognatha* biomass, Amph – *Amphipoda* biomass; Pred – predators, Prey – prey zooplankton, T50 – temperature in the upper 50-m layer, T50_100 – temperature in the 50–100 m layer, A50 – temperature anomaly in the upper 50-m layer, A50_100 – temperature anomaly in the 50–100 m layer; <32, 32–33, 33–34 – salinity classes; >2, 0–2, –2–0 – temperature classes; N, S, T – water mass transit to the north, south and total (respectively).

fall periods (Figs. 3 and 4). The exception was in the Aniva and Terpeniya bays in the fall of 1994 when the share of the CWS biomass was 39–43% (Fig. 4A and D). The CWS part of the biomass reached a maximum on slope and deep-water regions in the southeast off Sakhalin and in the south of 50°30′N (92–95% of the biomass). The main species of CWS group were composed of: *Thysanoessa raschii*, *Parasagitta elegans*, *Metridia okhotensis*, and *Pseudocalanus minutus*.

The major species of the zooplankton fauna were the moderate cold water species (MCW): *Calanus plumchrus*, *Metridia pacifica*, *Scolecithricella minor*, *Centropages abdominalis*, *Oithona similis*, etc., but they played less of a role in biomass formation compared with the cold water species (Fig. 5): 11–23% in spring, 12–35 % in fall with maximums found in Aniva and Terpeniya bays: 60 and 52%, respectively.

Warm water species (WWS) from south-boreal and subtropical biogeographic groups (*Calanus pacificus*, *Candacia bipinnata*, *Corycaeus sp.*, and *Sapphirina sp.*) were found in Aniva Bay and at the Sakhalin–Kunashir Line. Their share does not exceed the 2% level of the biomass. Other WWS represenatives with a wider propagation: *Neocalanus tenuicornis*, *Microsetella rosea*, *Oithona plumifera*, *Acartia clausi*, *Paracalanus parvus* were determined to make up to 10% of biomass in the fall (Fig. 5, for example, Aniva Bay, 1990).

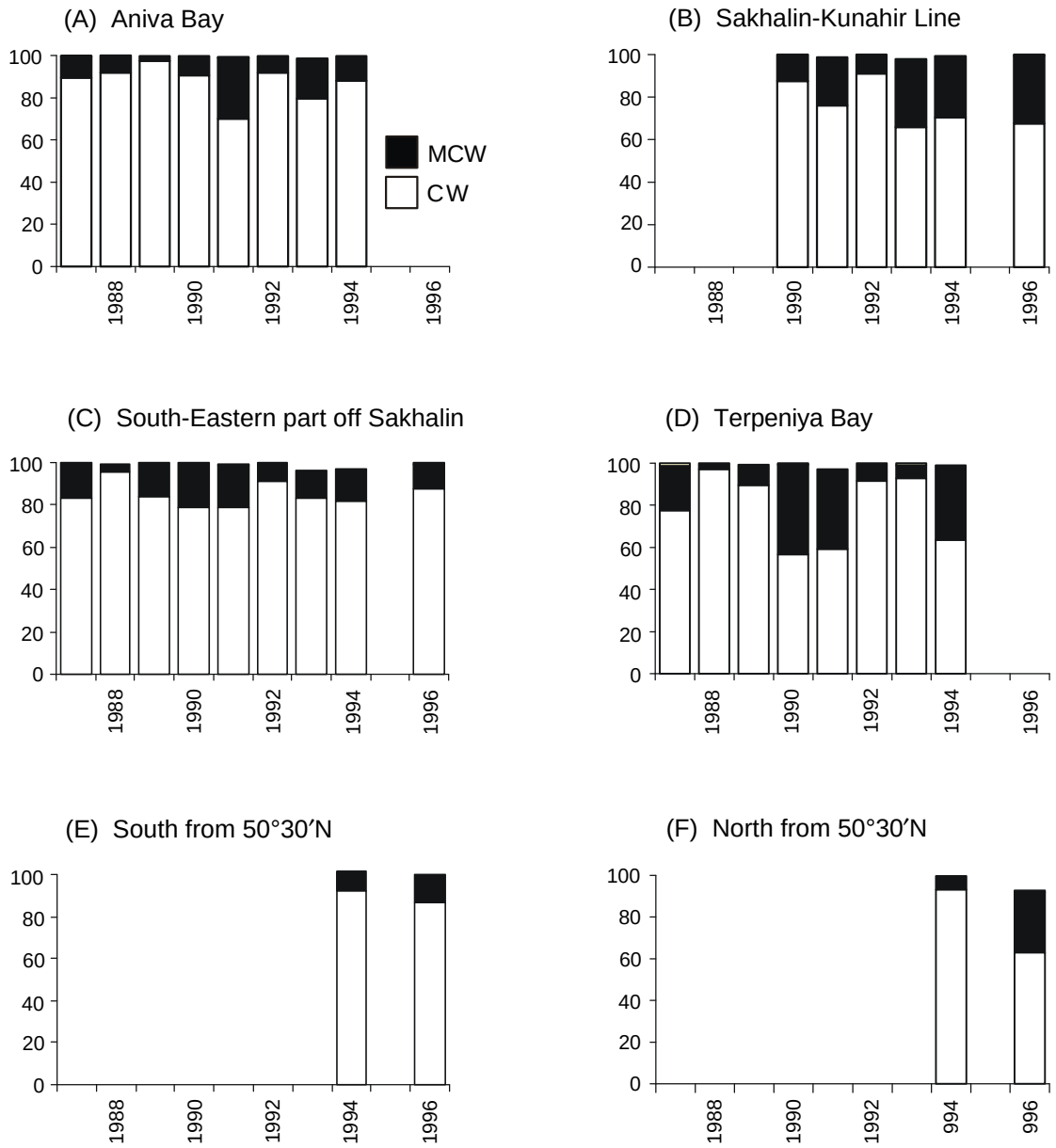

Fig. 4 Ecological group dynamics in the spring period (CW – cold water species, MCW – moderate cold water species; WWS – warm water species) by region and by the Sakhalin–Kunashir Line (lack of data for the northern shelf and slope is explained the presence of ice floes in post-spring and early summertime).

During the seasonal peak of warming period of the upper layer (early fall), the neritic complex actively grew: *Centropages abdominalis*, *Eurytemora herdmani*, *Tortanus discaudatus*, *Decapoda larvae*, *Gastropoda larvae*, *Bivalvia lar-vae*, etc., This phenomena especially characterized the bay regions where the biomass of the neritic share grew to 17–25% compared to spring time.

Carnivorous/Omnivorous Ratio

The predator fraction, having a predominance of *Parasagitta elegans*, had a wide range, from 2 to 75% of the biomass. The highest presence of predators was found in Aniva Bay (75%) and Terpeniya Bay (73%), but in different years (spring time). Peak of the carnivorous zooplankton can be noted in the appointed bays (Fig. 6).

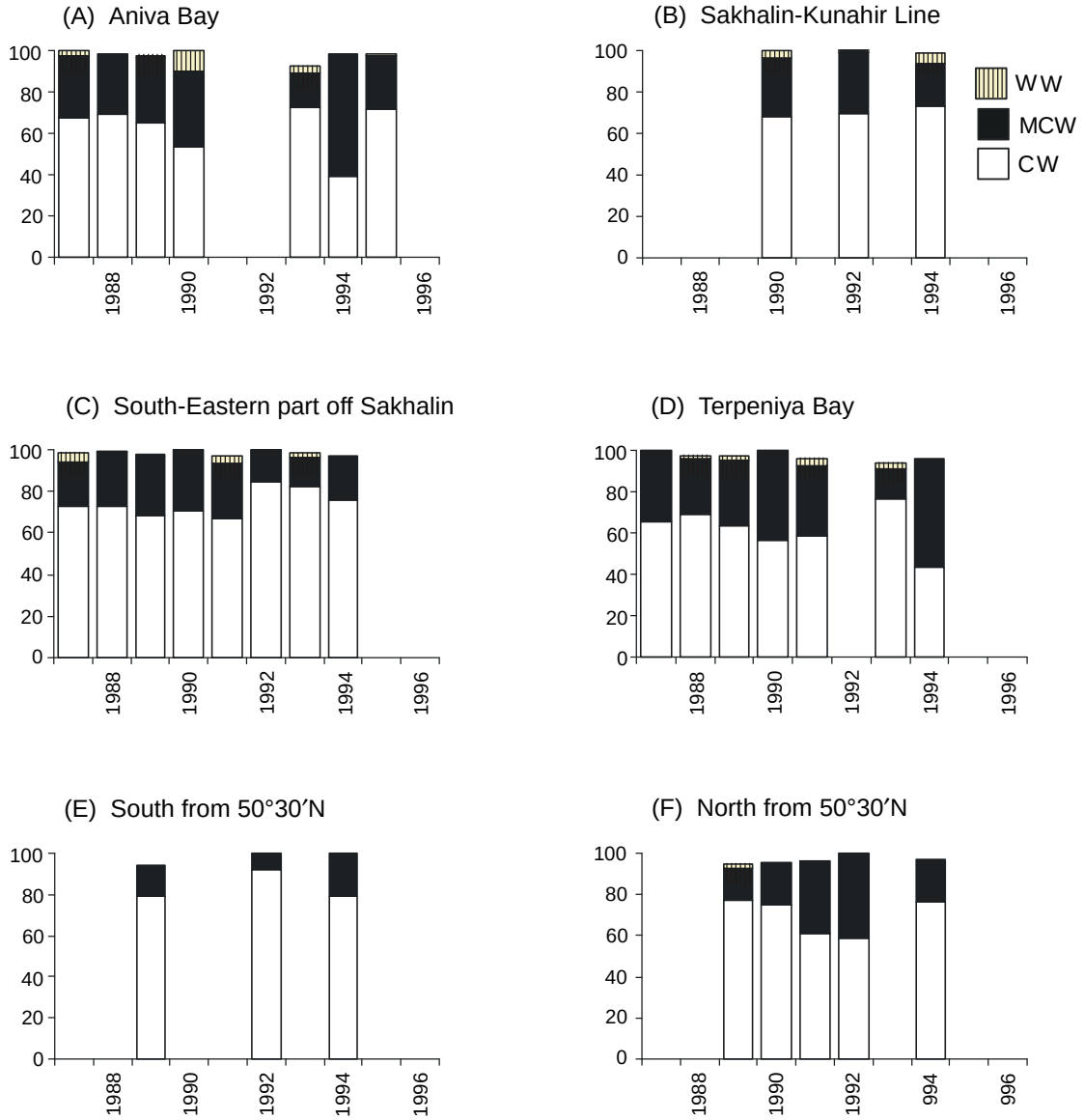

Fig. 5 Ecological group dynamics in the all period (CW – cold water species, MCW – moderate cold water species; WW – warm water species) by region and the Sakhalin–Kunashir Line.

Compared with springtime, predators in the fall season were obtained less often, except in the northeastern shelf of Sakhalin and the Sakhalin–Kunashir Line (Fig. 6 B, E and F). Nevertheless, the predator biomass absolute value varied from 102 to 140 mg/m^3 (averaged by regions) in the fall.

Conclusions

1) The seasonal and interannual variability magnitudes of the net zooplankton biomass were similar to each other. Independent from widely separated regions, biomass had an absolute minimum in the 1991. Preliminary investigation has shown a possible strong impact of the environment on the biomass, species structure and distribution of net zooplankton during last decade in the southwestern part of the Sea of Okhotsk. Biomass corresponded with layer temperature with negative correlation. Hence, in the cold years zooplankton biomass was greater than in warm years.

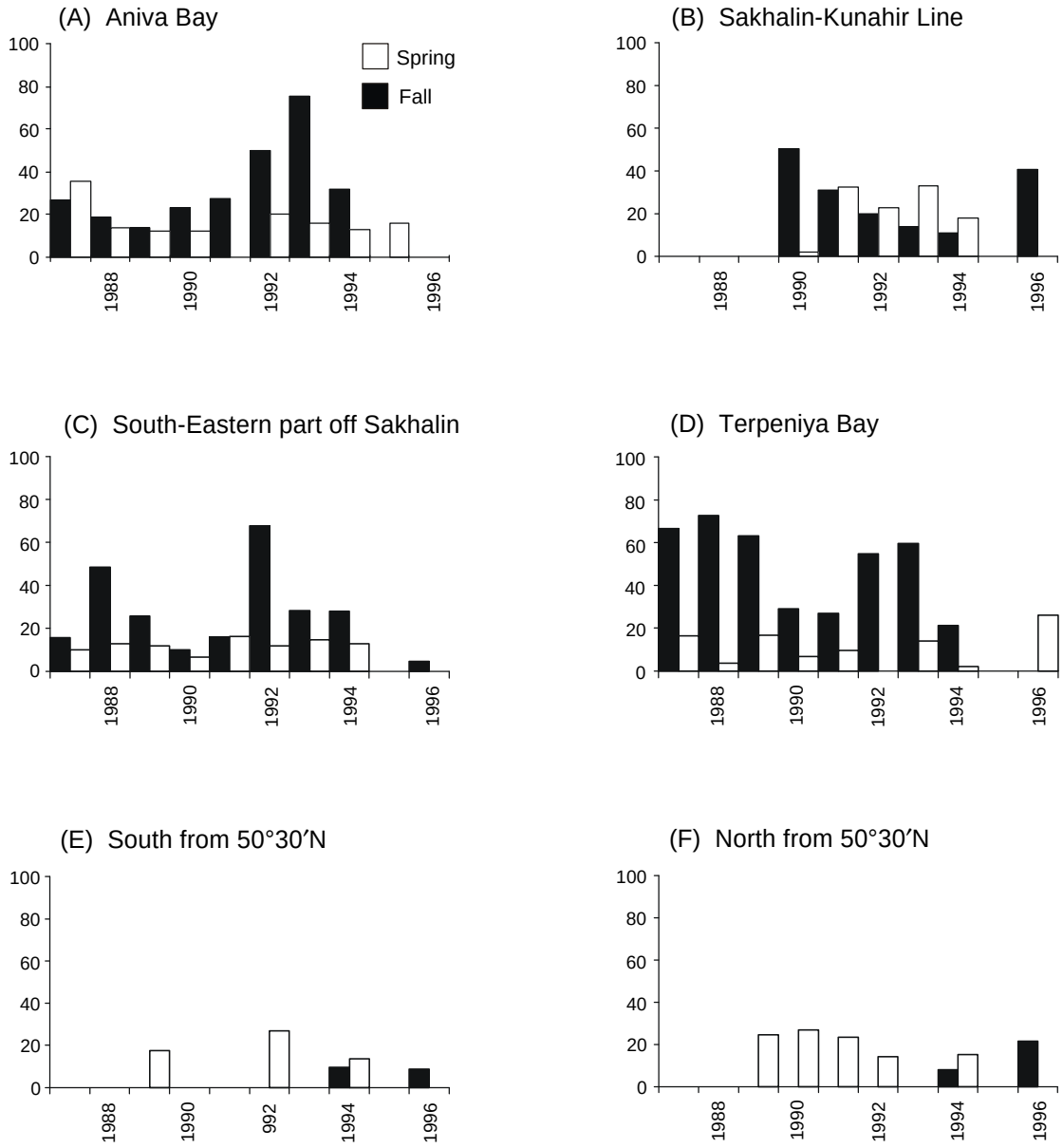

Fig. 6 Part of carnivorous zooplankton species (%) in biomass net zooplankton dynamics by region and the Sakhalin–Kunashir Line from 1987–1996.

2) Zooplankton fauna represented by a total of 88 forms belonging to 9 types and 15 classes. More diversity was obtained for the *Copepoda* and *Euphausiacea* taxons. Three plankter groups predominated in terms of biomass: *Copepoda*, *Euphausiacea*, and *Chaetognatha*.

3) The general ecological feature of the south-western part of the Sea of Okhotsk zooplankton was the predominance of the cold water species: *Thysanoessa raschii*, *Parasagitta elegans*, *Metridia okhotensis*, and *Pseudoclanus minutus*. Meanwhile, in the 1994 (Aniva and Terpeniya bays) cold water species were displaced by another group – moderate cold water species: *Centropages abdominalis*, *Calanus plumchrus*, and *Tortanus discaudatus*.

Appendix I

(Supplement to the paper *Geographical and Biological Characteristics of the Net Zooplankton in the South-Western Part Sea of Okhotsk during 1987-1996* by Irina Y. Bragina)

Species list of the net zooplankton in the south-western part of the Sea of Okhotsk according to an analysis of 1480 samples (1987–1996 SakhNIRO collection).

Phylum	Protozoa
Class	Sarcordina
Subclass	Rhizopoda
Order	Foraminifera
Family	Globigerinidae
Genus	*Globigerina*
	Globigerina bulloides
Phylum	Coelenterata
Subphylum	Cnidaria
Class	Hydrozoa
Subclass	Hydroidea
Order	Leptolida
Suborder	Athecata
Family	Tubulariidae
Genus	*Corymorpha*
	Corymorpha sp.
Family	Eudendriidae
Genus	Eudendrium
	Eudendrium ramosum
Suborder	Thecaphora
Family	Campanulariidae
Genus	Obelia
	Obelia longissima
Order	Trachylida
Suborder	Trachymedusa
Family	Trachynemidae
Genus	*Aglantha*
	Aglantha digitale
	Medusae sp.
Subclass	Siphonophora
Order	Calycophorida
Family	Dimophidae
Genus	*Dymophyes*
	Dymophyes arctica
Subphylum	Acnidaria
Class	Ctenophora
Subclass	Atentaculata
Family	Beroidae
Genus	*Beroe*
	Beroe cucumis
Phylum	Nemertini
	Nemertini, larvae
Phylum	Annelida
Class	Rotatoria
	Rotatoria sp.
Class	Polychaeta
	Polychaeta , larvae
Phylum	Arthropoda
Class	Crustacea
Subclass	Entomostraca
Order	Branchiopoda
Suborder	Cladocera
Family	Polyphemidae
Genus	*Evadne*
	Evadne nordmanni
Genus	*Podon*
	Podon leuckarti
Order	Ostracoda
Suborder	Myodocopa
Family	Conchoeciidae
Genus	*Conchoecia*
	Pseudoconchoecia borealis
	Conchoecia sp.
Order	Copepoda
Suborder	Calanoida
Family	Calanidae
Genus	*Calanus*
	Calanus plumchrus
	C. glacialis pacificus
	C. cristatus
	Neocalanus tenuicornis
Family	Eucalanidae
Genus	*Eucalanus*
	Eucalanus bungii
Family	Paracalanidae
Genus	*Paracalanus*
	Paracalanus parvus
Family	Pseudocalanidae
Genus	*Pseudocalanus*
	Pseudocalanus minutus
	Ps. gracilis
Genus	*Microcalanus*
	Microcalanus pygmaeus
Genus	*Clausocalanus*
	Clausocalanus arcuicormis
Family	Aetideidae
Genus	*Undinopsis*
	Undinopsis pacificus
Genus	*Gaidius*
	Gaidius brevispinus
Genus	*Gaetanus*
	Gaetanus simplex
Family	Euchaetidae
Genus	*E.marina*
Genus	*Pareuchaeta*
	Pareuchaeta japonica
Family	Scolecithricidae
Genus	*Scolecithricella*
	S.minor
Family	Themoridae
Genus	*Eurytemora*

	Eurytemora herdmani
	Eurytemora pacifica
Family	Metridiidae
Genus	*Metridia*
	Metridia pacifica
	M. okhotensis
Family	Centropagidae
Genus	*Centropages*
	Centropages abdominalis
Family	Candaciidae
Genus	*Candacia*
	Candacia bipinnata
Family	Pontellidae
Genus	*Epilabidocera*
	E. amphitrites
Family	Acartiidae
Genus	*Acartia*
	Acartia clausi
	A. longiremis
	A. tumida
Family	Tortanidae
Genus	*Tortanus*
	Tortanus derjugini
	T. discaudatus
Suborder	Cyclopoda
Family	Oithonidae
Genus	*Oithona*
	Oithona similis
	Oithona plumifera
Family	Oncaeidae
Genus	*Oncaea*
	Oncaea borealis
	O. conifera
Genus	*Corycaeus*
	Corycaeus sp.
Suborder	Harpacticoida
Family	Ectinosomidae
Genus	*Microsetella*
	Microsetella rosea
Family	Harpacticidae
Genus	*Harpacticus*
	Harpacticus sp.
Genus	*Sapphirella*
	Sapphirella sp.
	Copepoda, Nauplii
	Copepoda, Ova
Order	Cirripedia
Suborder	Thoracica
Family	Balanidae
Genus	*Balanus*
	*Balanus sp.st.*Naupl.
	*Balanus sp.st.*Cypris
Subclass	Malocostraca
Order	Cumacea
Family	Diastylidae
Genus	*Diastylis*
	Diastylis bidentata
Order	Amphipoda
Suborder	Hyperiidea
Family	Hyperiidae
Genus	*Parathemisto*
	Parathemisto japonica
	P. libellula
Order	Euphausiacea
Family	Euphausiidae
Genus	*Euphausia*
	E. pacifica
Genus	*Thysanoessa*
	Th. raschii
	Th. longipes
	Th. inermis
	Euphausiidae st. Furcilia
	Euphausiidae st. Caliptopis
	Euphausiidaest. Naupl.
	Euphausiidae st. Ova
Order	Decapoda
Suborder	Macrura
Family	Hippolithidae
Genus	*Spirontocaris*
	Spirontocaris,
Genus	*Eualus*
	Eualus, larvae
Family	Crangonidae
Genus	*Nectocrangon*
	Nectocrangon, larvae
Genus	*Sclerocrangon*
	Sclerocrangon salebrosa, larvae
Suborder	Anomura
Family	Paguridae
Genus	*Pagurus*
	Pagurus sp., larvae
Family	Lithodidae
Genus	*Paraithodes*
	Paralithodes camtschatica, larvae
Genus	*Hapalogaster*
	Hapalogaster grebnitzkii, larvae
Suborder	Brachyura
Family	Majidae
Genus	*Hyas*
	Hyas coarctatus, larvae
Genus	*Chionoecetes*
	Chionoecetes opilio, larvae
Genus	*Erimacrus*
	Erimacrus isenbeckii, larvae
Phylum	Mollusca
Class	Gastropoda
	Gastropoda larvae
Order	Pterapoda
Suborder	Gymmnosomata
Family	Clionidae
Genus	*Clione*
	Clione limacina
Suborder	Thecosomata
Family	Limacinidae
Genus	*Limacina*
	Limacina helicina
Class	Bivalvia
	Bivalvia, larvae
Class	Cephalopoda

	Cephalopoda, larvae
Phylum	Tentaculata
Class	Phoronidea
	Phoronidea, larvae
Class	Chaetognatha
Genus	*Parasagitta*
	Parasagitta elegans
Phylum	Echinodermata
Class	Asteroidea
	Asteroidea, larvae
Class	Echinoidea
Order	Diadematoidea
Family	Strongylocentrotidae
Genus	*Strongylocentrotus*
	Strongylocentrotus sp., larvae
Class	Holothuroidea
Order	Dendrichirota
Family	Cucumariidae
Genus	*Cucumaria*
	Cucumaria japonica, larvae
Phylum	Chordata
Subphylum	Tunicata
Class	Appendicularia
Genus	*Oikopleura*
	Oikopleura labradoriensis
Genus	*Fritillaria*
	Fritillaria borealis

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