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Zooplankton Production in the Toyama Bay in March–May, 1978

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Abstract

The production of six crustacean species of zooplankton in the coastal areas of Toyama Bay is calculated by two methods, age-class analysis and Ikeda's physiological method, based upon the plankton samples obtained in spring season of 1978. Mean daily production-biomass ratios for six species calculated differed between the two methods, but the approximate mean value is estimated at 0.05, and the daily production at 0.5 mg in dry weight or 2.5 mg in wet weight per 1 m^3 of water.

The methods of the estimation of the biological production of zooplankton communities have achieved certain levels with theoretical backgrounds, but many problems must be resolved in the practical techniques (OMORI and IKEDA 1976) particularly in marine environment. To estimate the carrying capacity of salmon fry for artificial mass release, the productivity of zooplankton as prey for the fry must be measured in the area concerned. The present trials are to estimate it by two indirect methods based upon the zooplankton samples obtained in the coastal waters of Toyama Bay during the spring season of 1978.

I. Material and Method

Five series of 10–15 days interval zooplankton samplings were made with Norpac net (0.33 mm × 0.36 mm mesh openings) by vertical haul from a depth of 10 meters or less to the surface on board a small fishing boat at 12 stations in the coastal area of eastern Toyama Bay on the Japan Sea (Fig. 1), March 17–May 9, 1978. Zooplankters were counted by species and developmental stages, and the mean distribution density of each form in each series was computed (Table 1).

The weight of each form was not measured and was referred from the data of the Barents, Okhotsk and Bering Seas zooplankton by BOGOROV (1957, Table 2). To convert the dry weight from wet weight of zooplankton it was assumed that the dry/wet weight ratio is 0.2*. Two methods, namely, age-class analysis and physiological method have been adopted for the present estimation of the zooplankton production.

1. Age-Class Analysis

When we postulate a cohort which consisits of N_0 individuals with a mean body

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* OMORI (1969) computed the mean water content of zooplankton of 81.1% from the results of measurement for 32 species.

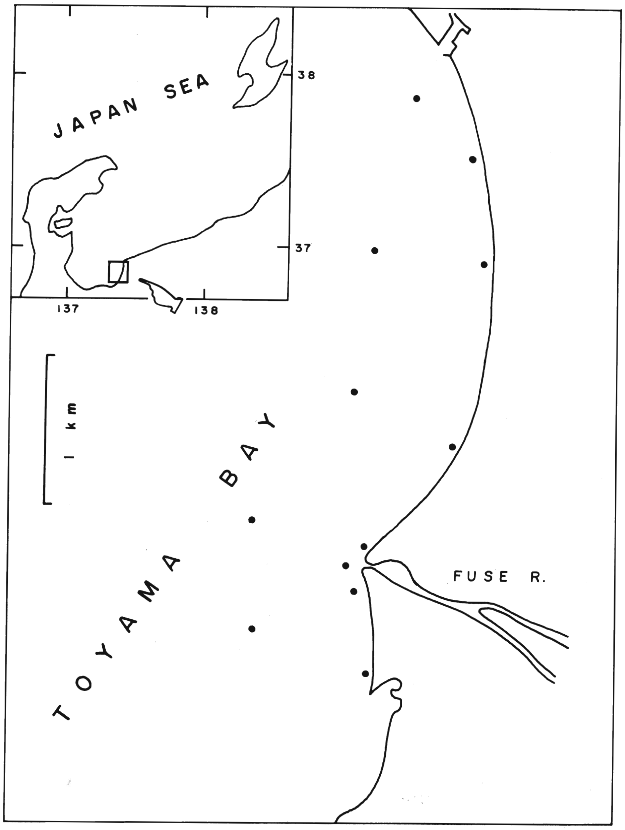

Fig. 1. Location of zooplankton sampling stations in the Toyama Bay, March–May, 1978.

Table 1. Mean distribution density of zooplankton in each species and developmental stage (organisms/m^3) and assumed developmental process of the species in the Toyama Bay, March–May, 1978.

Cruise No.		I	II	III	IV	V
Date		Mar 17	Mar 28	Apr 11	Apr 25	May 9
No. of staions		6	11	12	12	12
Calanus pacificus	VI	0.1	0.1	0.1	0.7	2.4
	V	0.1	0.1	0.4	25.8	12.2
	IV	0.1	0.1	1.3	39.9	49.2
	III			0.8	18.9	22.7
	II	0.2		0.1	2.8	8.6
	I					1.0
Calanus plumchrus	V				8.3	0.1
	IV		0.5	2.5	18.4	
	III	0.1	6.0	8.3	14.4	
	II	0.8	23.7	3.5	2.9	
	I		11.7	0.7	0.1	

Table 1. Continued.

Paracalanus parvus	VI	46.0	34.2	15.8	28.6	28.8
	V	11.2	34.1	8.8	1.4	8.9
Pseudocalanus minutus	VI	29.7	9.4	111.0	133.5	1.5
	V	9.4	7.0	19.1	1.6	
Metridia lucens	VI		0.1			
	V	0.2		0.7	7.6	
	IV	1.8	0.2	6.3	0.7	
	III	1.3	0.4	13.7		
	II			0.1		
Euphausia pacifica	Furcilia			0.4	15.7	6.5
	Caliptopis		0.1	25.2	351.1	25.7
	Ova	0.1		21.3	0.2	

Table 2. Mean weight of zooplankton from the Barents, Okhotsk and Bering Seas (mg of raw weight, BOGOROV 1957),

	Copepodite stages					
	VI	V	IV	III	II	I
Calanus pacificus	1.72	1.19	0.44	0.13	0.06	0.03
Calanus plumchrus	3.10	3.05	0.67	0.28	0.06	0.02
Paracalanus parvus	0.03	0.025	0.015	0.012	0.009	
Pseudocalanus minutus	0.08	0.07				
Metridia lucens	0.32	0.16	0.10	0.05	0.02	0.01
	Furcilia		Calyptopis		Ova	
Euphausia pacifica	0.15		0.06		0.02	

weight W_0 at time t_0, and of N_1 individuals with a mean weight W_1 at time t_1, the production (P, gross production) and the biomass consumed or mortality (M) during the period t_0 to t_1 are presented (BOUGIS 1976) by:

$$P=\frac{1}{2}(N_0+N_1)(W_1-W_0) \quad \text{.............................} \quad (1)$$

$$M=\frac{1}{2}(N_0-N_1)(W_0+W_1) \quad \text{.............................} \quad (2)$$

In these, the number of indivduals ordinally decreases and the weight of a plankter increases with time. At the same time, we also observe the population which increases in number during the period t_0 and t_1. These may be the new broods and/or the population transported from other water masses. The amount of it, recruitment (R), is fomulated as follows:

$$R=\frac{1}{2}(N_1-N_0)(W_0+W_1) \quad \text{.............................} \quad (3)$$

Similarly, the mortality (M) in formula (2) includes the numbers which scattered and disppeared from the population. The feature of the growth was supposed on the basis of the developmental stage composition tracing the maximum age-class in number throughout the investigation period (Table 1).

2. Physiological Method

IKEDA (1974) demonstrated that the rate of respiration of zooplankton is well correlated to body weight and habitat temperature by the measurements for 112 species obtained from the boreal, temperate and tropical regions of western Pacific; for the *W* mg dry weight animal which inhabits at temperture of T °C, the respiration rate R (μl O_2/animal/hr) is given as follows;

$$R = a \cdot W^b \quad \cdots\cdots (4)$$

where $a = 10^{0.02438T - 0.1838}$ and $b = -0.01089T + 0.8918$. Assuming that the respiration quotient of zooplankton is 0.8 (TANIGUCHI 1975), formula (4) gives daily respiration rate R (mg C/animal/day):

$$R = 0.8 \times \frac{12}{22.4} \times \frac{1}{1000} \times 24\, a \cdot W^b$$

$$= 0.01029\, a \cdot W^b \quad \cdots\cdots (5)$$

According to IKEDA and MOTODA (1975), when diggestive efficiency is 0.7 and the gross growth efficiency is 0.3, net production of zooplankton is given as;

$$P = 0.75\, R \quad \cdots\cdots (6)$$

Assuming again the carbon/dry weight ratio of zooplankton is 0.4**, daily production of a zooplanker on the basis of dry weight is derived from formulae (5) and (6);

$$P = 0.01929\, a \cdot W^b \quad \cdots\cdots (7)$$

For the practical manual use of formula (7), it is convenient to introduce the ratio of production to the biomass, P/B ratio, of zooplankton dividing P in formula (7) by the weight of the zooplankter, *W*, as follows;

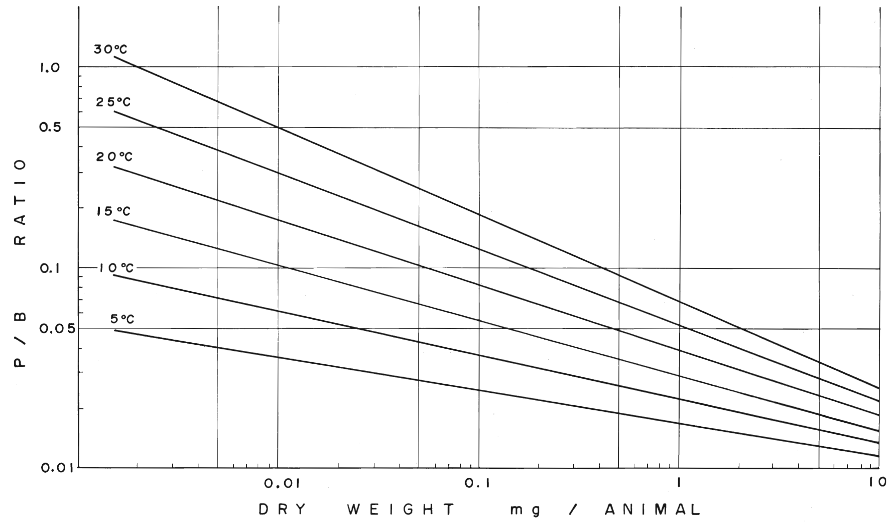

Fig. 2. Daily production-biomass ratio against body size at different temperatures which zooplankton inhabit (introduced from IKEDA 1974).

** In the carbon-dry weight diagram of IKEDA (1974) the carbon content seems to be concentrated at ca. 40–45% of dry weight. OMORI (1969) showed the mean value obtained for 33 species is 42.0%.

$$\frac{P}{B}=0.01929\,a\cdot W^{b-1} \qquad (8)$$

Formula (8) gives Fig. 2 which shows the daily P/B ratio against animal size in dry weight at each habitat temperature.

The surface temperature was measured at all stations throughout the survey period, and the mean values at the depth of 5 m in each series were obtained. It was 8.8° C on March 17 and 13.9° C on May 9 with a gradual increase. The distribution density of zooplankton and the temperature used for the calculation in formula (7) or (8) are those of mean values between the two cruises t_0 and t_1.

II. Results and Discussion

Table 3 gives the results of the present calculation of production, recruitment and mortality of six species of zooplankton by age-class analysis. *Calanus pacificus* and *Paracalanus parvus* achieved entirely no production and *Euphausia pacifica* only a little. This was due to the fact that the relative composition of age in each species was constant as a rule during the survey period. In spite of this, the recruitment in

Table 3. Production, recruitment and mortality (mg dry weight/m³) for Toyama Bay zooplankton through five cruises in March–May, 1978 (age-class analysis).

		Cruise No.					Daily P/B	Daily (P+R)/B
		I–II	II–III	III–IV	IV–V	I–V		
Calanus pacificus	Production	0	0	0	0	0	0	
	Recruitment	0	0.198	10.151	1.578	11.927		0.063
	Mortality	0.002	0	0	4.552	4.554		
Calanus plumchrus	P	0	1.215	0	5.033	6.248	0.050	
	R	0.719	0.003	4.024	0	4.746		0.088
	M	0	1.108	0	13.291	14.399		
Paracalanus parvus	P	0	0	0	0	0	0	
	R	0.115	0.044	0.077	0.039	0.274		0.023
	M	0.071	0.237	0.037	0	0.345		
Pseudocalanus minutus	P	0	0	0	2.112	2.112	0.036	
	R	0	1.795	0.360	0	2.155		0.072
	M	0.358	0	0.245	0.022	0.626		
Metridia lucens	P	0	0	0.391	0	0.391	0.010	
	R	0.006	0.278	0.007	0	0.291		0.018
	M	0.047	0.006	0.516	0.257	0.827		
Euphausia pacifica	P	0.002	0	0	0	0.002	0.000	
	R	0	0.398	4.370	0	4.768		0.072
	M	0	0	0.084	4.182	4.266		
Total	P	0.002	1.215	0.391	7.145	8.753	0.018	
	R	0.840	2.716	18.990	1.616	24.161		0.067
	M	0.479	1.351	0.883	22.304	25.017		

C. pacificus and mortality in *C. plumchrus* is high. In the sum total of the six species the production (gross production) is lower than the mortality that is nearly equal to the recruitment. The P/B ratio is high in *C. plumchrus* and *Pseudocalanus minutus* while in the others it is rather low, showing the mean of 0.018 for total animals. This is located in the lower realm of the previous values listed by Bougis (1976, Table 4). The mortality (M) consists of natural death and predation by higher

Table 4. Previous values of production (P) and daily P/B ratio of zooplankton (compiled by Bougis 1976).

Organism or group	Geographical area	Period	P mgC/m²/day	Daily P/B	Reference[a]
Zooplankton	Georges Bank	year	200	0.03	Riley 1947
Zooplankton	English Channel	year	75	0.10	Harvey 1950
Zooplankton	Long Island Sound	year	166	0.17	Conover 1956
Zooplankton	North Sea (North)	Apr–Sept	180	0.048	Steele 1958
Euphausia pacifica	Pacific (NE)	year	0.9	0.008	Lasker 1966
Herbivorous copepods	North Sea	Jan–June	4.9	0.08	Cushing 1969
Copepods (mainly *Calanus*)	North Sea	Mar–June	46	0.10	Cushing and Vucetic 1963
Copepods (mainly *Calanus*)	North Sea	Mar–June	15	0.033	Mullin 1969
Calanus finmarchicus	Barents Sea (East)	year	7.8	0.002	Kamshilov 1958
Calanus helgolandicus	Black Sea	June	28	0.15	Petipa 1967
Calanus plumchrus	Strait of Georgia	Mar–May	51	—	Parsons *et al.* 1969
Acartia clausi	Black Sea (Bay)	June	15	0.17	Petipa 1967
Acartia clausi	Black Sea	June	6.6	0.23	Petipa 1967
Acartia clausi	Black Sea	year	0.38	0.035	Greze and Baldina 1964
Acartia clausi	Mediterranean (NW)	—	0.33	0.05	Gaudy 1970
Acartia tonsa	Chesapeake Bay	summer	77	0.50	Heinle 1966
Centropages kröyeri	Black Sea	summer	0.19	0.077	Greze and Baldina 1964
Centropages typicus	Mediterranean (NW)	—	0.9	0.05	Gaudy 1970
Centropages typicus	Mediterranean (NW)	year	7.75	0.06	Razouls 1972
Temora stylifera	Mediterranean (NW)	June–Nov	2.04	0.05	Razouls 1972

[a]) not given in the reference list of the present paper.

animals and emigration to other areas in the present definition. Therefore, certain amounts of the mortality may contribute to the prey for the young fish in the presnet area. The recruitment (R) may also be an important part of the potential food for the predators. When the amount of recruitment (R) is added to the production (P), the mean P/B ratio counts for 0.067.

The results of calculation by the formula introduced from Ikeda (1974) are shown in Table 5. The productivity per unit weight of a zooplankter is higher in the smaller animals which appear in the warmer period, and *vice versa*. P/B ratio ranged from 0.032 to 0.073 with a mean of 0.049 for the six species. These values lie at almost median in the range of many previous values. Whether the values obtained in the present trial are appropriate or not, it may be difficult to give a definite conclusion in the present stage of this field.

Table 5. Mean biomass and daily production of zooplankton (both in mg dry weight per 1 m^3) in Toyama Bay, March–May, 1978.

Cruise No.	I–II		II–III		III–IV		IV–V		I–V		
Period	Mar 17–28		Mar 28–Apr 11		Apr 11–25		Apr 25–May 9		Mar 17–May 9		
Days	10		13		13		14		50		
	B	P	B	P	B	P	B	P	B	P	P/B
Calanus pacificus	0.068	0.002	0.167	0.006	5.342	0.197	9.605	0.410	3.795	0.168	0.044
Calanus plumchrus	0.375	0.017	0.789	0.034	4.607	0.096	4.216	0.151	2.497	0.080	0.032
Paracalanus parvus	0.354	0.023	0.257	0.017	0.156	0.011	0.198	0.018	0.241	0.017	0.070
Pseudocalanus minutus	0.428	0.022	1.146	0.062	2.101	0.122	1.091	0.078	1.191	0.074	0.062
Metridia lucens	0.035	0.020	1.370	0.076	1.518	0.089	0.149	0.090	0.768	0.046	0.060
Euphausia pacifica	0.001	0.000	0.200	0.012	2.542	0.155	2.594	0.192	1.334	0.097	0.073
Total	1.260	0.066	3.929	0.207	16.267	0.671	17.852	0.858	9.826	0.482	0.049
Mean temperature (°C)	9.3		9.75		10.5		12.6				

B: biomass P: production

As the mean biomass of the six crustacean species during 50 days was 9.8 mg in dry weight or 49.1 mg in wet weight per 1m^3, if the daily P/B ratio is 0.05, an approximate mean value obtained by two present methods, daily production of zooplankton is estimated at ca. 0.5 mg in dry weight or 2.5 mg in wet weight per 1 m^3. The six species of crustaceans under consideration occupy ca. 60–90% in weight in total net plankton collected.

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1978年春季富山湾沿岸の動物プランクトン生産量

森 岡 泰 啓

要　旨

1978年3月中旬から5月上旬の50日間に富山湾の沿岸域で5回のプランクトン採集を行ない，動物プランクトン生産量の見積りをふたつの方法によって試みた．プランクトン標本は富山湾布施川口の浅海域の12地点でノルパックネットの10mから表面までの鉛直曳で得られた．主要橈脚類5種およびオキアミ1種，計6種について発育段階ごとに個体数を算えて海水1㎥あたりの分布密度を得た．水深5mの温度は，はじめ8.8℃で少しずつ上昇し，終りには13.9℃となった．

IKEDA (1974) の，動物プランクトンの体重とそのプランクトンが棲息する環境水温から生産量を算出する方法によると全調査期間の1日あたりの平均P/B比（生物量に対する生産量の比）は0.049となり，いまひとつの方法，すなわち齢期解析法では0.018となった．しかし，後者の方法では調査海域内に移入した群および移出した群を勘定に入れていないので生産量をかなり過少に評価したことになる．P/B比を0.05とするならば，平均生物量は乾重量で9.8mg/㎥，湿重量では49.0mg/㎥であったから，調査期間における1日あたりの生産量は乾重量で0.5mg/㎥そして湿重量では2.5mg/㎥となる．