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DAILY RATION AND FOOD CONSUMPTION IN COD FROM EASTERN BALTIC

by

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Abstract

Feeding dynamics of cod in natural conditions is analysed using methods of mathematical statistics and chance theory. Daily ecological ration for various size-weight groups of cod is determined.

The total amount of food consumed by cod is estimated on the basis of data on food composition, daily ration by size and season and cod abundance.

Resume

En se servant des méthodes de statistique mathématique et des calculs des probabilités on a fait l'analyse de la dynamique de nutrition dans vingt-quatre heures de la morue dans les conditions naturelles et on a déterminé la ration "écologique" journalière pour divers groupes selon la dimension et le poids de la morue.

Sur la base des données concernant la composition de la nourriture et l'assouvissement des alevins et de la grande morue suivant les saisons, sa biomasse et le taux de la ration journalière, on a déterminé la quantité de nourriture par la morue.

Method of daily ration calculation

Ration determination was based on daily observation on cod feeding in natural conditions in subdivisions 26,28 of the Baltic Sea.Samples were taken in autumn and spring period in one 48-hour and four 24-hour stations at interval of 2-4 hours.

Analysis and calculation were made separately for fish in length groups 10-20cm, 20-30cm and above 30cm.

Initial information was cosidered as samples from random variable - stomach filling index X (weight of stomach content per gram of fish body weight in prodecimille).

Theoretical distributions of filling index were determined using observed data, and the dynamics of stomach content was investigated using these distribution functions.

Hystogram analysis (Fig.I) shows that empirical distribution density $f^{*}(x)$ of random variable X may be satisfactorily described by truncated normal distribution with density

$$f(x)=\frac{c}{\sigma\sqrt{2\pi}}\exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right](0\leq x<\infty),$$

where: μ, σ - parameters of truncated normal distribution

$$1/c=\frac{1}{\sigma\sqrt{2\pi}}\int_0^{\infty}\exp\left[-\frac{(x-\mu^2)}{2\sigma^2}\right]dx=\Phi\left(\frac{\mu}{\sigma}\right)$$

$\Phi(x)$ - Laplace function.

Parameters μ and σ were found equating the first initial (Mx) and the 2nd central (Dx) moments of theoretical distribution of their sample estimates $\bar{x}$ and s^2.

All calculations necessary to solve corresponding transcendental equations and obtain values of theoretical probability density function $f(x)$ and distribution function $F(x)$ were done by computer. Typical examples of theoretical curves $f(x)$ are brought in Fig.I.

All samples contained an essential amount of cod with empty stomachs.Therefore, to find the theoretical frequency of fish with empty stomachs an equivalent class J_0 is defined as follows.

Plotting the hystogram, the fishes with empty stomachs were included in the first class $J_1(0\leq x<x_1)$. Then, the probability P_0 of occurrence in the sample of fish with empty stomach was assumed to be $P_0=\int_0^{x_0}f(x)dx$,

or to be equal to the probability of the random variable X to get into the equivalent class $J_0\,(0\leq x<x_0)$,

where $x_0=\frac{m_0^*}{m_1^*}x$,

m_0^* and m_1^* - number of fish with empty stomach and all fish, included in the first class correspondingly.

Using the values obtained by graphical smoothing method, curves of empty stomach share in a sample (%) depending on time were plotted (Fig. 2).

The rate of changes of empty stomachs share was determined for every curve.

The following stage comprises the analysis of dynamics of amount of food in cod stomach for the sample of size n.

The range of index variability is divided in intervals by ppints

$$0 < x_0 < x_1 < \ldots\ldots < x_{i\,max}$$

$x_{i\,max}$ is chosen to satisfy the condition $F(x_{i\,max}) \geq 0{,}98$, that is the probability of index value larger than $x_{i\,max}$ does not exceede 0,02. Taking $x_i = 20_i\,(i = 1,2,\ldots\ldots, i_{max-1}$ 20 - interval size in prodecimille) we ensure sufficient precision of calculation.

For each interval $x_{i-1} < x < x_i\,(i = 1,2,\ldots\ldots, i_{max})$ we find - mean index of fullness $\bar{x}_i$ probability P_i to get into interval for the random variable X , expected number m_i of fish, total weight of food in cod stomach Q_i in grams, according to formulae:

$$\left.\begin{aligned} \bar{x}_i &= \frac{1}{2}(x_{i-1} + x_i) \\ P_i &= \int_{x_{i-1}}^{x_i} f(x)\,dx \\ m_i &= P_i\, n \\ Q_i &= m_i\, \bar{x}_i\, \bar{W}/10000 \end{aligned}\right\} (i = 1,2,\ldots\ldots, i_{max}$$

where $\bar{W}$ - is mean weight (in grams) of a separate fish in the examined size group, and 10 000 - is a coefficient for conversion to weight. Besides, number of fishes with empty stomach is expected to be $m_0 = P_0\, n$, where P_0 is determined above.

The amount of food $Q(t)$ in the stomachs of all the fishes in the given sample is expressed by formula

$$Q(t)=\sum_{i=1}^{i max} Q_i + (n-\sum_{i=0}^{i max} m_i)\bar{x}_{i max} \bar{W}/10000 \text{ at time } t.$$

In this formula the last item is added to account food in the stomachs of fish having theoretical index values exceeding $x_{i max}$. The calculated smoothed curves of dependence of amount of food upon time $Q(t)$ are represented in Fig.3.

The length of the period of the curve $Q(t)$ is determined by physiology of cod feeding. One or more cycles (one of them being principal) consisting of two parts each - of period, when feeding is dominating, and of period of prevailing digesting can be distinguished on these curves.

Judging by dynamics of number of empty stomachs, by hystograms of indices of fullness and their mean values, one can conclude that, even at the basis minimum of amount of food in the stomach Q_{min} some part of fish feeds on actively; but in the principal maximum Q_{max} up to 10-30% of fish can be with empty stomachs.

Thus the form of the curve $Q(t)$ as well as the values of basic Q_{min} and Q_{max} are also determined by different feeding rhythms of individual fish.

To calculate the mean daily ration we divide the area under the curve $Q(t)$ in two parts conventionally:

1. a constant part (background), having height Q_{min}, i.e. the least amount of food in the stomachs during a cycle;

2. a variable part, the form of which is determined by changes of feeding intensity in the course of 24-hr cycle.

As Q_{min} is a constant value, the amount of food eaten and the amount of food digested are balanced i.e. each component member is $Q_{min}/2$.

For a variable part let us assume, that $t_i (1 \le i \le 2k)$ are successive time moments at which $Q(t)$ acquires minimum for add i and maximum for even i values.

The mean daily ration for one fish is expressed by the formula:

$$R=\frac{\sum_{i=1}^{k}[Q(t_{2i})-Q(t_{2i-1})]}{nT}+\frac{Q_{min}}{2n}=\frac{2\sum_{i=1}^{k}[Q(t_{2i})-Q(t_{2i-1})]+TQ_{min}}{2nT},$$

where n - fish number in a sample

T - number of 24-hr periods.

Discussion

The number of empty stomachs per 24-hr cycle being analysed, two types of curves were revealed (Fig.2).

1. curves with two maximum and two minimum values ($P_{o\,max\,1}$ $P_{o\,max\,2}$ and $P_{o\,min\,1}, P_{o\,min\,2}$);

2. curves with one maximum and one minimum ($P_{o\,max}$ and $P_{o\,min}$).

In case of the first type curve, the rate of change in the number of fish with empty stomachs is high and makes up to 2.0-4.2%/hr. Morning and evening food intake peaks, and night and day decrease are observed. Nevertheless, the fish feeds rather intensively during all the 24 hours; the stomach fullness being about 90-220%oo. This type is characteristic for cod that consumes mysidacea and worms.

For the second type curve the maximum number of fish with empty stomachs is observed at night and in the morning. The number of empty stomachs is relatively hihg at any time. The amount of food in stomachs of cod is low (50-70%oo). The rate of change in number of fish with empty stomachs is 1.3-1.9 %/hr, i.e. the rate is considerably lower than in the case of intensive feeding (the first type curve). The rate of food digestion is low. The charācter of the second type curves and their parameters makes it possible to suggest food defficiency.

The described above method of calculation of daily ration takes into account the dynamics of full and empty stomachs, which reflects food availability and peculiarities of its digestion in

natural conditions. Mean statistical " ecological"
ration is lower than that obtained in vitro experiments, where fish is force-fed.

Daily "ecological" ration of young and adult cod ranges in 0.60 - 2.25 % of body weight (Tab. I). In case of good feeding the ration makes up to I.0 - 2.25 %, while in unfavourable conditions is 0.6 - 0.8 %.

In annual ration calculations seasonal peculiarities in the amount of food in the cod stomach were taken into account and the following values of daily ration were assumed:

Young fish, I half year - I.0 %
II " - I.3 %
Adult fish, July - February - I.0%
March - April - 0.9%
May - June - 0.5%

Food consumption by cod

Composition and size of annual ration was determined on the basis of the data on food composition, daily ration by size and season and cod abundance.

The young cod inhabits coastal areas in July - January and in February - June - deeper zone: adult fish also concentrates in coastal areas in August - January and on the spawning grounds in February - July.

Food composition of young and adult cod differs by seasons (Tab.2-4).

In 1975-1978 the yearly total amount of food consumed by cod made up on the average I mln tons (Clupeidae - 300 thousand tons, invertebrate - 700 thousand tons (Tab. 5).

The share of herring in cod food in 1976 - 1978 has decreased as compared with 1975 that was partly caused by the decrease in large cod stock.

Sprat consumption in 1975 was low, and in 1976 - 1978 was very high: it was connected with the paculiarities in distribution of cod and sprat during the years of aeration and stagnation in the Gotland Deep (Uzars, "Peculiarities of Feeding and Quantitative Food Consumption of Eastern Baltic Cod",C.M.P:4, I975).

In I978 the decrease in Mesidotea entomon and Mysidacea consumption and the increase in the share of worms in the cod food was observed. The sharp decrease in Mysidacea consumption, perhaps, was connected with growth of young cod stock in I977 - I978.

These investigations on cod feeding give the possibility to determine the influence of the fish-consumer on prey stock and the role of the consumer in ecosystem.

Table 1

Daily ration of cod

Date	Size class, cm	Mean weight of cod, g	Daily ration, g	Daily ration, % body weight
4-6 IX 1965	10-20	42	0.57	1.36
12-14 III 1970	10-20	13.5	0.21	1.56
4-6 IX 1965	20-30	155	2.80	1.81
1-2 X 1966	20-30	179	1.45	0.81
8-9 X 1966	20-30	164.5	0.98	0.60
9-10 IV 1966	20-30	107	1.05	0.98
4-6 IX 1965	>30	524	6.80	1.30
1-2 X 1966	>30	403	3.30	0.80
8-9 X 1966	>30	410	3.20	0.78
12-14 III 1970	>30	871	6.05	0.69
9-10 IV 1966	>30	667	15.00	2.25

Table 2

Feeding characteristics of young cod (5 - 20 cm)

Year	Season	Stomach filling index %o	Food composition in % by weight				
			Mysis sp.	Pontoporeia sp	Harmothoe sarsi	Other invertebr.	Other fish
1974-75	Sep.-Jan.	77	76	24	-	-	-
1975-76	"	74	74	5	19	2	-
1976-77	"	139	64	3	32	1	-
1977-78	"	117	80	10	4	5	1
1978-79	"	49	13	1	22	64	-
1975	Mar.-Jun.	35	39	-	59	2	-
1976	"	82	26	2	51	15	-
1977	"	68	15	-	82	-	3
1978	"	51	9	4	70	17	-

Table 3

Feeding characteristics of young cod (20 - 30 cm)

Year	Season	Stomach filling index %o	Food composition in % by weight							
			Mysis sp.	Mesidotea ent.	Pont. sp.	Harmothoe sarsi	Other invertebr.	Herring	Sprat	Other fish
1974-75	Sep.-Jan.	137	22	37	10	7	9	1	1	13
1975-76	"	95	38	16	26	20	-	-	-	-
1976-77	"	135	47	6	17	24	-	-	2	4
1977-78	"	134	22	14	29	7	23	-	-	5
1978-79	"	32	6	16	19	47	1	1	10	-
1975	Mar.-Jun.	65	7	22	1	49	-	15	6	-
1976	"	184	2	10	9	20	47	3	6	3
1977	"	168	8	7	-	36	-	3	46	-
1978	"	83	9	14	8	30	3	2	34	-

Table 4

Feeding characteristics of adult cod (above 30cm).

Year	Month	Stomach filling index, ‰	Food composition in % by weight						
			Herring	Sprat	Other fish	Mesidotea ent.	Mysis sp.	Harmothoe sarsi	Pontoporeia sp.
1975	Jan.	64	23	18	9	41	3	3	3
	Mar.-Apr.	88	36	6	17	31	–	10	–
	May- Jun.	65	10	–	–	11	–	79	–
	Sep.-Dec.	130	21	2	10	46	6	10	5
1976	Jan.	119	10	5	1	28	29	3	24
	Mar.-Apr.	95	9	54	2	21	3	6	5
	May -Jun.	60	15	34	6	9	2	34	-
	Sep.-Dec.	115	17	10	7	16	15	12	23
1977	Jan.	99	19	7	7	16	35	15	1
	Mar.-Apr.	119	24	50	8	4	1	13	–
	May -Jun.	110	12	57	2	6	4	18	1
	Sep.-Dec.	128	18	19	13	35	9	2	1
1978	Jan.	83	9	5	11	44	7	10	14
	Mar.-Apr.	99	9	59	–	21	4	–	8
	May -Jun.	–	6	16	15	47	1	14	1
	Sep.-Dec.	70	8	49	3	24	1	10	5
1979	Jan.	61	18	20	12	30	2	13	5
	Mar.-Apr.	79	22	52	1	19	1	4	1

Table 5

Food consumption by cod (in thousand tons)

	Year	1975			1976			1977			1978		
	Group*)	1	2	3	1	2	3	1	2	3	1	2	3
	Cod biomass	90	281	371	44	259	303	63	182	245	188	190	378
Food items	Herring	18	197	215	2	124	126	1	113	114	7	102	109
	Sprat	7	49	56	5	185	190	15	159	174	49	155	204
	Mesidotea ent.	53	373	426	11	145	156	7	139	146	68	202	270
	Mysis sp.	93	35	128	47	119	166	100	74	174	69	36	105
	Harmathoe sarsi	105	137	242	41	79	120	90	36	126	338	26	364
	Others	50	118	168	52	187	239	39	55	94	122	94	216
	Total	326	909	1235	158	839	997	252	576	828	653	615	1268

*) 1 - young cod

2 - adult cod

3 - total

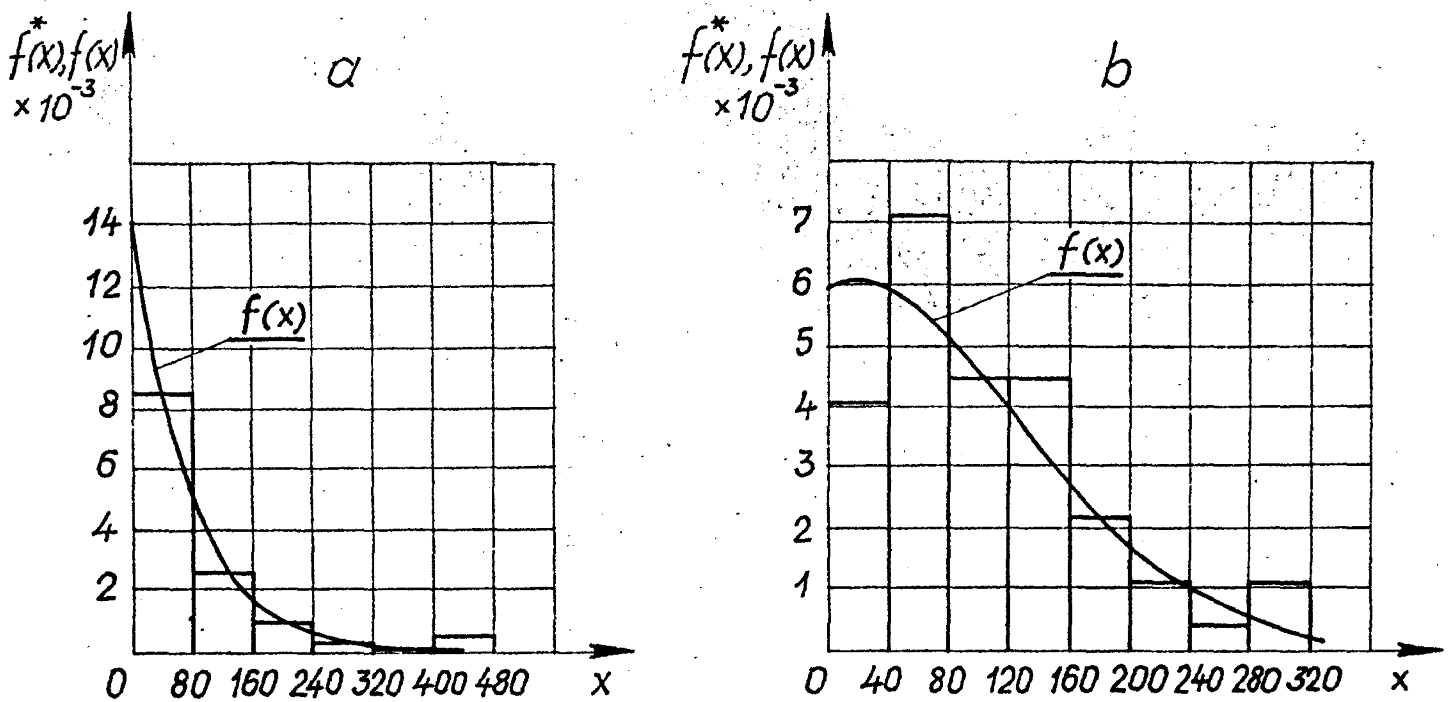

Figure 1.

Examples of hystograms and theoretical curves $f(x)$ of distribution of fullness of cod stomachs

a) 8 - 9 IV 1966, 8 PM; size group 20 - 30 cm;

b) 4 - 6 IV 1965, 10 - 11 PM: size group 10 - 20 cm.

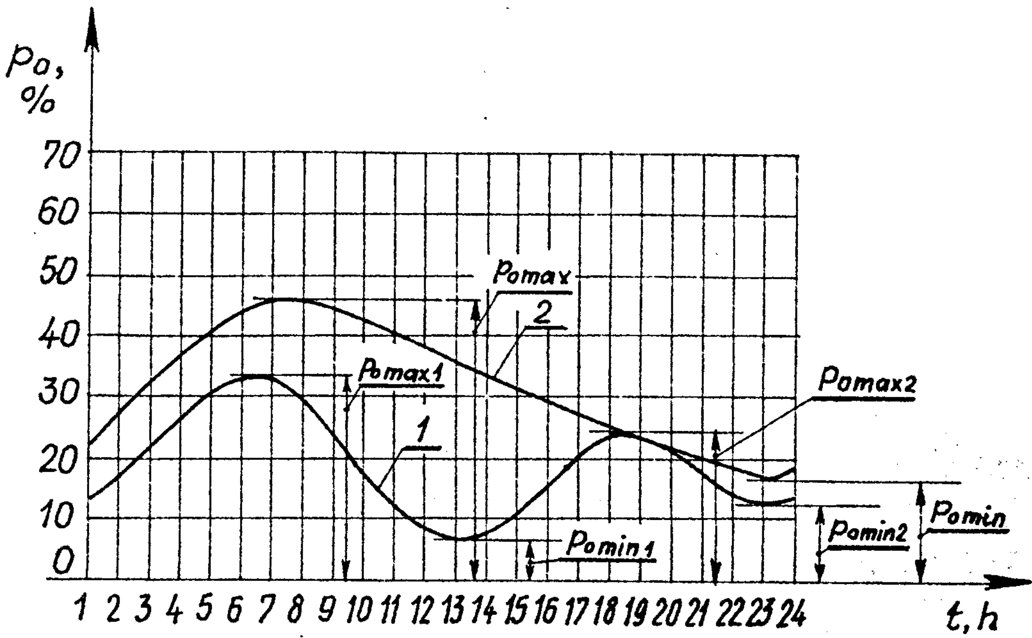

Figure 2.

Examples of daily dynamics of fish number with empty stomachs.

1) 4 - 6 IX 1965, size group 10 - 20 cm:

2) 1 - 2 X 1966, size group 20 - 30 cm.

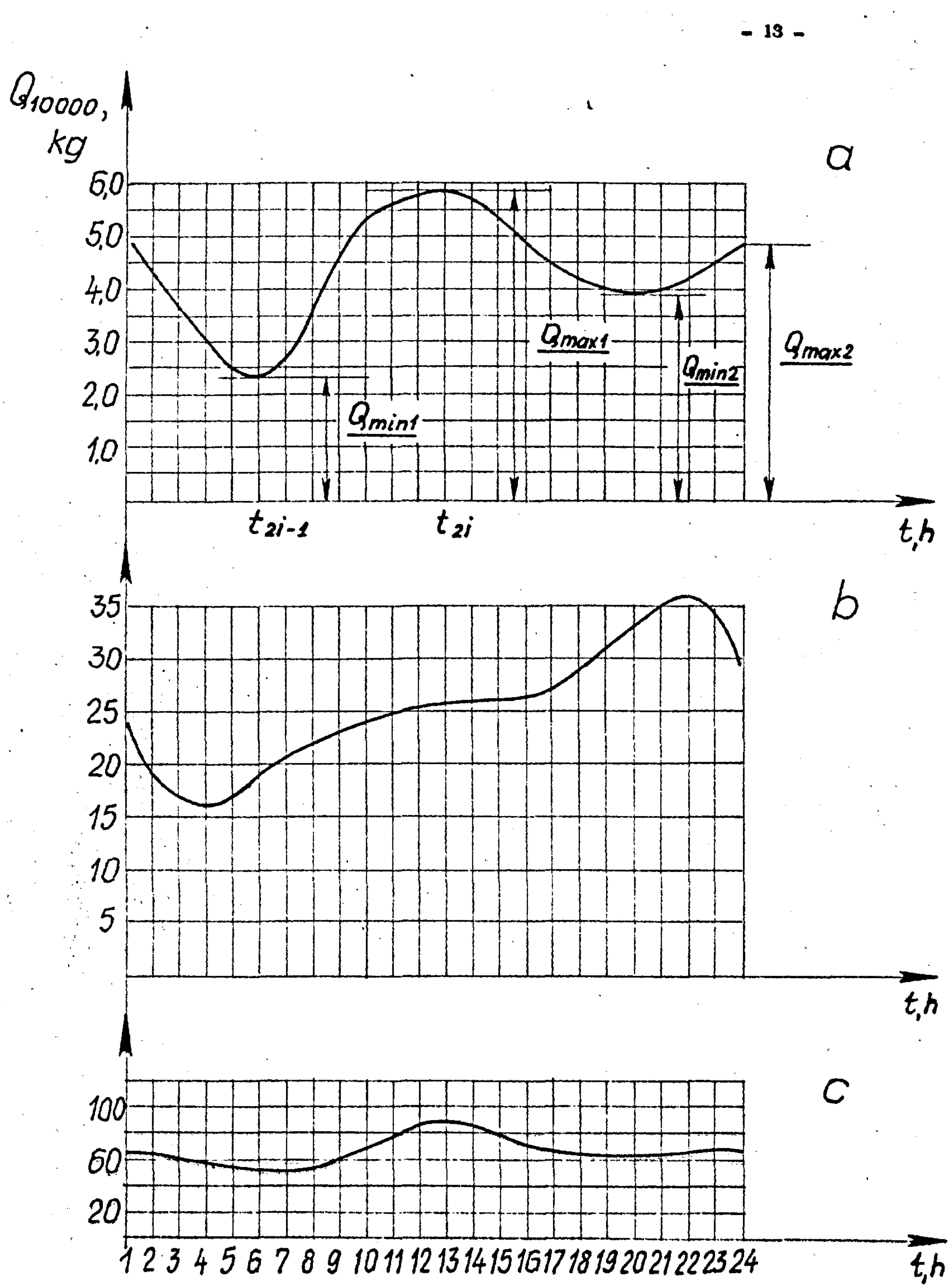

Figure 3.

Daily dynamics of food mass for the sample of size

n = 10 000 (24-hr station, 4 - 6 IX 1965).
a - size group 10 - 20 cm, b - 20 - 30 cm, c - >30 cm.