FEEDING PATTERNS OF NINE SPECIES OF ANTARCTIC FISH AND ASSESSMENT OF THEIR DAILY FOOD CONSUMPTION

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Abstract

Little is known about the feeding patterns of non-commercial fish species in Antarctic waters. The aim of this study is to collect information on the feeding patterns of several commercially non-targetted species in the Indian Ocean sector of the Southern Ocean: Nototheniidae (four species), Channichthyidae (three species) and Bathydraconidae (two species). The study concentrated on analysing the food composition of these species to find out their daily diet. One 36-hour station was carried out in the Kosmonavtov Sea (67°50'S; 41°24'E) in March 1988. All samples were taken from the depth range 300 to 350 m and a total of 1 165 stomachs were collected and analysed. The species studied were classified into the four following categories: (i) *Chaenodraco wilsoni* and *Trematomus eulepidotus* - planktivorous species with euphausiids, mainly *Euphausia superba*, being the staple food; (ii) *Trematomus centronotus* - a benthophage feeding mainly on amphipods, mobile and sedentary forms of polychaetes, with *Euphausia superba* also comprising a considerable portion of its diet; (iii) *Trematomus hansoni* - a euryphage; (iv) *Dissostichus mawsoni, Cygnodraco mawsoni, Gymnodraco acuticeps, Chionodraco hamatus* and *Cryodraco antarcticus* - predators feeding mainly on fish. The daily diet of these species was from 1 to 4% of their body weight. Annual food consumption by these species was calculated to be about five times their body weight.

Résumé

Les habitudes alimentaires des espèces de poissons non commerciales dans les eaux de l'Antarctique sont très peu connues. Cette étude a pour but de rassembler des informations sur les habitudes alimentaires de plusieurs espèces non visées commercialement dans le secteur Indien de l'océan Austral, notamment : Nototheniidae (quatre espèces), Channichthyidae (trois espèces) et Bathydraconidae (deux espèces). L'étude est axée sur l'analyse de la composition de l'alimentation de ces espèces pour découvrir leur régime alimentaire quotidien. Une station de 36 heures a été effectuée dans la mer Kosmonavtov (67°50'S; 41°24'E) en mars 1988. Tous les échantillons ont été prélevés de la zone de profondeur 300 - 350 m. Un total de 1 165 estomacs ont été recueillis puis analysés. Les espèces étudiées ont été classifiées en quatre catégories : i) *Chaenodraco wilsoni* et *Trematomus eulepidotus* - des espèces planctonophages dont l'aliment de base est l'euphausiidé, notamment *Euphausia superba*; ii) *Trematomus centronotus* - une espèce benthophage qui se nourrit principalement d'amphipodes, de différentes sortes de polychètes mobiles ou sédentaires, et dont une grande partie du régime se compose

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d'*Euphausia superba*; iii) *Trematomus hansoni* - une espèce euryphage; iv) *Dissostichus mawsoni, Cygnodraco mawsoni, Gymnodraco acuticeps, Chionodraco hamatus* et *Cryodraco antarcticus* - des prédateurs se nourrissant principalement de poissons. La quantité de nourriture absorbée quotidiennement par ces espèces variait entre 1 à 4% de leur poids corporel. Il a été calculé que leur consommation annuelle de nourriture correspond à environ 5 fois le poids de leur corps.

Резюме

До сих пор еще недостаточно известно о питании антарктических рыб, на которые не ведется коммерческого промысла. Целью настоящего исследования является сбор информации о питании нескольких коммерчески не эксплуатируемых видов в индийском секторе Южного океана: Nototheniidae (четыре вида), Channichthyidae (три вида) и Bathydraconidae (два вида). Это исследование направлено на анализ состава пищи этих видов в целях изучения их суточного рациона. Одна суточная станция была выполнена в море Космонавтов (67°50'ю. ш.; 41°24'в. д.) в марте 1988 г. Все пробы были собраны на глубине 300-350 м. В общей сложности было собрано и проанализировано 1 165 желудков. Изученные виды были подразделены на следующие четыре категории: (i) *Chaenodraco wilsoni* и *Trematomus eulepidotus* -планктофаги, в питании которых преобладали эвфаузииды, преимущественно *Euphausia superba;* (ii) *Trematomus centronotus* - бентофаг, потребляющий главным образом амфиподы, подвижные и оседлые формы полихет; *Euphausia superba* также составляет большую часть рациона; (iii) *Trematomus hansoni* -эврифаг; (iv) *Dissostichus mawsoni, Cygnodraco mawsoni, Gymnodraco acuticeps, Chionodraco hamatus* и*Cryodraco antarcticus* - хищники, питающиеся, в основном, рыбой. Суточный рацион этих видов колебался в пределах 1-4% от массы тела. Годовое потребление пищи составило около 5 масс тела.

Resumen

Se sabe muy poco del tipo de alimentación de las especies no explotadas comercialmente en aguas antárticas. El objetivo de este estudio es reunir información sobre el tipo de alimentación de varias especies que no han sido objeto de pesca comercial en el sector Indico del océano Austral: Nototheniidae (cuatro especies), Channichthydae (tres especies) Bathydraconidae (dos especies). El estudio se concentró en el estudio de la dieta diaria de estas tres especies mediante el análisis de la composición de alimentos. Se realizó una estación de 36 horas de duración en el mar de Kosmonavtov (67°50'S; 41°24'E) en marzo de 1988. Todas las muestras se tomaron entre los 300 - 350 m de profundidad, recogiéndose unos 1 165 estómagos para su posterior análisis. Las especies estudiadas se clasificaron en cuatro categorías:

(i) *Chaenodraco wilsoni* y *Trematomus eulepidotus* - son especies planctófagas, que se alimentan de eufáusidos, siendo *Euphausia superba*, el componente habitual; (ii) *Trematomus centronotus* - es una especie bentófaga que se alimenta principalmente de anfípodos y de poliquetos móviles y sedentarios, además de *Euphausia superba*, que forma una parte importante en su dieta; (iii) *Trematomus hansoni* - es una especie eurífaga; (iv) *Dissostichus mawsoni*, *Cygnodraco mawsoni*, *Gymnodraco acuticeps*, *Chionodraco hamatus* y *Cryodraco antarcticus* - son especies depredadoras que se alimentan básicamente de pescado. La dieta diaria de estas especies oscilaba entre el 1 y el 4% de su peso corporal. El consumo anual de estas especies se calculó en cinco veces el peso corporal de la especie.

1. INTRODUCTION

Our knowledge of the feeding behaviour of Antarctic fish is very limited despite the existence of numerous publications on the subject. Feeding patterns of commercial fish has usually been studied in order to evaluate annual consumption of krill, and more often than not in the Atlantic sector of the Southern Ocean (Permitin, 1970; Kock, 1985). There is only scant information on the feeding patterns of non-commercial fish species, but the level of krill consumption by these species might be substantial. This study was aimed at collecting information on the food composition of several commercially non-targeted species in the Indian Ocean sector of the Southern Ocean: Nototheniidae (four species), Channichthyidae (three species) and Bathydraconidae (two species). Another aim was to discover their daily level of food consumption.

One 36-hour station was carried out in the Kosmonavtov Sea (67°50' S; 41°25'E) on 23 to 24 March 1988. Adult specimens were taken from the depth range 300 to 350 m at a rate of one sample each 4 hours. Biological analyses of fish were carried out according to standard procedures (Anon., 1974). Food boluses were collected from fish stomachs and analysed. Food items were identified by species and also ranged according to their level of digestion (fresh, half-digested, completely digested). A total of 1 165 stomachs of nine fish species were processed in this way.

In calculating daily consumption it was assumed that food evacuation from fish stomachs corresponds to an exponential function (Tyler, 1970 and Montgomery *et al.*, 1989). In this case, food evacuation rate is:

$$\frac{dS}{dt} = -AS \qquad (1)$$

where S - amount of food at a given time,
t - time,
A - constant.

From equation (1) it follows that the amount of food in a particular stomach varies according to the equation:

$$S(t) = S\,(0) \exp\,(-At) \qquad (2)$$

where $S\,(0)$ - amount of food at time $t = 0$.

Equation (2) clearly shows that 90% of food is evacuated over a time of T_{90} (evacuation time):

$$T_{90} = \frac{\ln 0.1}{A} \cong \frac{2.3}{A} \quad (3)$$

Evacuation time is from two to five days for Antarctic fish (Grawford, McLeave as cited in Targett, 1981; Montgomery *et al.*, 1989). In accordance with equation (3) the constant value A = 0.048 - 0.019 when T_{90} is within the above-mentioned range. The mean specific daily consumption (C_W) was calculated according to Pennington's equation (Krasnoper, 1988):

$$C_W = [yAT\text{-}y(0)+y(T)]\ \frac{24}{T} \bullet 100 \quad (4)$$

where C_W is expressed in percent of body mass,
y - mean index of stomach fullness,
A - constant from (3) corresponding to the particular evacuation time,
T - duration of observations (36 hours),
$y(0)$ and $y(T)$ mean indices of stomach fullness at the beginning and end of observations respectively.

Daily food consumption for each fish species was calculated for two values of T_{90}: 48 and 72 hours. The corresponding values of A are 0.048 and 0.032.

In order to compare consumption rates we also calculated approximate daily consumption according to metabolic rate and the index

$$K_2 = \frac{P}{P+R}$$

where P - production
R - metabolic rate.

The parameter K_2 was taken to be 0.2. Therefore, $\frac{P}{R} = 0.25$. Since the amount of consumption $C_w = \frac{P+R}{U}$, where the assimilation index, U, is taken to be 0.8, we obtain the value $C_W = 1.56R$. In order to calculate R, we used the following equations for the basal metabolic rates for cold-water fish (Chekunova, 1983): $R_{st1} = 0.187\ W^{0.783}$ ml 0_2 hr^{-1} for most species and $R_{st2} = 0.039W^{0.891}$ ml 0_2 hr^{-1} for *Chionodraco hamatus* and *Cryodraco antarcticus*.

If under normal environmental conditions $R=2Rst$ (Vinberg, 1956), then specific daily consumption would be:

$$C_{w_1} = \frac{6.8 \bullet W^{-0.2}}{q} \quad (5)$$

$$C_{w_2} = \frac{1.42 \bullet W^{-0.2}}{q} \quad (6)$$

where: C_W is expressed in percent of body mass;
W - mean body mass (g);
q - food calorific content, assumed to be 1 kcal g^{-1}.

Information on food composition of fish species studied is presented in Table 1. According to this table all species may be classified in the following way:

(i) *Chaenodraco wilsoni* and *Trematomus eulepidotus* - planktophagic species with euphausiids, mainly *Euphausia superba*, being the staple food. *T. eulepidotus* also consumes a substantial amount of myctophids (*Electrona antarctica*) and juvenile nototheniids (mainly *Pleuragramma antarcticum*);

(ii) *Trematomus centronotus* - benthophagic species, feeding mainly on amphipods, mobile and sedentary forms of polychaetes (Table 1). *Euphausia superba* also comprises a considerable portion of the diet of *T. centronotus*;

(iii) *Trematomus hansoni* - euryphagic species. However, food scraps from vessels comprised almost half of sampled stomach contents (Table 1) which significantly distorted the results for this species;

(iv) *Dissostichus mawsoni, Cygnodraco mawsoni, Gymnodraco acuticeps, Chionodraco hamatus* and *Cryodraco antarcticus* - predators, feeding mainly on fish (Table 1). The diet of *D. mawsoni* contained *T. eulepidotus* (38% by weight), *T. hansoni* (6%), *Chaenodraco wilsoni* (13%), myctophids (12%) and juvenile *P. antarcticum* (9%). The diet of *C. mawsoni* and *G. acuticeps* comprised of juvenile fish of almost all species inhabiting the survey area, including their own juveniles. However, the major food items of *G. acuticeps* were the myctophids, *E. antarctica* (21%) and *Gymnoscopelus spp* (25%), and for *C. antarctica* - the fairly uncommon species *Aethotaxis mytopteris* (25%). The main food items for *Chionodraco hamatus* and *Cryodraco antarcticus* were first-year matured *C. wilsoni* (SL=17-20 cm) (37% each), *P. antarcticum* (15 and 22% respectively) and *T. eulepidotus* (17 and 19%).

All fish sampled had been intensively feeding, with *C. wilsoni* and perhaps *G. mawsoni* being the exceptions. The mean index of stomach fullness ranged from 2.2 to 3.9% of body mass (Table 2). It is impossible to be specific about feeding intensity in relation to *D. mawsoni* due to a lack of data. The feeding behaviour of *C. wilsoni* at the time of the survey may have been affected by a range of oceanological conditions (Gerasimchuk and Trotsenko, 1988). This is quite likely since samples collected on the same day some 4 to 5 n. miles from the station position showed a high rate of feeding for *C. wilsoni* (index of stomach fullness was 2 to 4% of body mass).

Following analysis of stomach contents and comparing food at various stages of digestion, we concluded that the actual digestion time for plankton-eaters and benthophages is no less than two or three days, while for predatory and euryphages digestion takes no less than three or four days. This is in total agreement with the experimental data presented earlier.

Some scientists (Novikova, 1949; Kogan *et al.*, 1963) believe that changes in the stomach fullness index over time can be viewed as an indicator of processes occurring within the targetted population, i.e. falls in the index are interpreted as food digestion while increases are seen as consumption. Differences between consecutive values of the index are used to estimate digestion rates which in turn are used to calculate consumption. In our opinion this approach is unsuitable for sea fishes. Populations of sea fishes consist of many schools, each containing several dozen or a few hundred individuals. There is a much greater degree of uniformity of behaviour of specimens within a particular group (school) compared with other groups. Each group behaves as a unit and its members feed simultaneously. However, there is obviously some correlation of behaviour among groups which have certain similarities as species. On average, such groups might consume the same amount of food over several days but the amount of food in their stomachs at any given moment can vary significantly. Each population sample is obtained after trawling three miles for one hour and, since we do not know why fish tend to group together, we cannot say how many groups make up the catch. Figure 1 shows the weight distribution of *T. hansoni* in two consecutive samples. If one assumes that schooling patterns are determined by age or size, then the first sample is formed by one group and the second one by at least two. Figure 2 shows consecutive changes in the mean stomach fullness index, mean body weight and the amount of fresh food recorded over the observation period in respect of *T. hansoni.* The data in Figures 1 and 2 indicate that changes in the index are not indicative of the process of the stomach becoming full or of food evacuation. Rather, these changes are brought about by size differences among specimens and decreases in the amount of fresh food as the overall stomach fullness index increases.

The case of *C. wilsoni* is somewhat different. Body weight for this species in consecutive samples did not differ significantly and the population was of one age class. However here we came across an increase in the index of stomach fullness over four hours due to heavily digested food which had been in the fishes' stomachs more than one day. Obviously in this case different groups of fish were analysed separately.

Modelling was used to study fish feeding patterns and to check the methods used in this field of study. Parameters studied within the fish population were specific body weight and food evacuation rate. Both of these indices displayed a degree of inconsistency which is characteristic of a real population. At random times (but at a specific part of the day) fish received portions of food corresponding to the weight of prey they would consume in the wild. The likelihood of food portions being taken was fitted so that over three days they received an amount of food corresponding to their normal consumption. Levels of stomach fullness were studied for a random group of 25 specimens (i.e. observation was simulated). Results of modelling indicated that such random feeding is sufficient to obtain a clear picture of changes in the stomach fullness index such as occur in natural conditions. Changes in the fullness index over time were caused by random sampling and not by consumption and food evacuation patterns themselves.

Calculated daily and yearly consumption turned out to be small (Table 2) and for the following species were: *Chaenodraco wilsoni** - 2.5% and 5.8%; *Trematomus eulepidotus* and *T. centronotus*- 2.0% and 4.6%; *Dissostichus mawsoni* and *T. hansoni* - 3.5% and 8.1%; *Gymnodraco acuticeps* 4.0% and 9.2%; *Cygnodraco mawsoni* - 1.0% and 3.0%; *Chionodraco hamatus* - 1.6% and 3.5% and *Cryodraco antarcticus* - 2.2% and 4.0%. The mean annual rate of consumption for these fish is about five times their body weight. The average amount of consumption for the waters of eastern Antarctica, which has a mean biomass density in the order of 4.6 to 5.1 thousand km^2 can be calculated using Shust's data. An annual food base production of no less than 20 to 25 thousand km^2, is required for a biomass of this size. If one assumes that the mean biomass of bottom and near-bottom dwelling fish is 12 to 13 million tonnes (Lubimova and Shust, 1980) then the yearly consumption rate of Antarctic fish is between 60 and 65 million tonnes.

* Consumption for *C. wilsoni* was minimal (about 0.6% of body weight) due to inactive feeding. Such a low value is uncharacteristic for this species. According to data obtained from the Kosmonavtov Sea, daily consumption by this species is usually about 2.5% of body weight (Pakhomov and Shumatova, 1988). This is the value we took for our estimate of annual consumption by *C. wilsoni.*

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Table 1: Food composition in fish (percentage of food by weight) sampled at a 36-hour station in the Kosmonavtov Sea - 23 to 24 March, 1988.

Food Items	*C. wilsoni*	*T. eulepidotus*	*T. hansoni*	*T. centronotus*	*D. mawsoni*	*C. mawsoni*	*G. acuticeps*	*C. hamatus*	*C. antarcticus*
E. superba	84.6	52.2	1.97	32.9	2.0	1.1	2.3	1.9	0.1
Other Euphausiids	5.8	10.2	0.03	0.8	1.0	0.4	0.05	0.6	+
Mysidacea	-	-	0.1	0.2	0.7	1.6	0.02	0.1	-
Amphypoda	0.03	0.8	0.7	12.6	+	3.8	0.03	-	-
Isopoda	-	-	0.2	1.0	-	0.03	-	-	-
Decapoda	-	-	-	0.8	-	0.4	0.05	-	0.2
Gastropoda	-	-	2.6	0.1	-	-	-	-	-
Teuthida	-	-	1.4	3.7	2.1	-	0.3	-	-
Pteropoda	-	0.2	-	-	-	-	-	-	-
Polychaeta	-	0.05	6.5	41.4	-	1.7	0.07	-	-
Tunicata	-	1.2	0.1	2.7	0.1	-	-	-	-
Fish eggs	-	-	29.5	1.1	-	-	0.07	-	-
Myctophidae	5.1	23.5	0.4	0.3	12.0	1.4	52.3	14.5	-
Nototheniidae	4.5	11.4	10.4	2.1	82.1	89.1	44.8	82.9	99.7
Vessel waste	-	-	45.6	-	-	-	-	-	-
Other food	-	0.4	0.54	0.3	-	0.1	-	-	-
Soil elements	-	-	0.1	0.01	-	0.4	0.02	-	-
Number of stomachs examined	250	219	243	43	52	197	84	58	21

Table 2: Percentage of daily food consumption of the examined fish at a 36-hour station in the Kosmonavtov Sea - March 1988.

Species	Number of Specimens	Mean Body Weight $\omega \pm \sigma$ (g)	Mean Index of Stomach Fullness	Food Evacuation Rate	Daily Food Consumption as % of Body Weight	Daily Food Consumption as per Vinberg's Formula
Chaendraco wilsoni	250	180 ± 2[1] (104 - 288)[2]	0.009 ± 0.001 (0 - 0.1)	48 72	0.9 0.6	2.4
Trematomus eulepidotus	219	118 ± 6 (50 - 650)	0.022 ± 0.001 (0 - 0.094)	48 72	2.8 1.9	2.6
Trematomus hansoni	243	380 ± 20 (100 - 1350)	0.038 ± 0.002 (0 - 0.157)	48 72	5.2 3.7	2.1
Trematomus centronotus	43	97 ± 10 (48 - 433)	0.036 ± 0.004 (0 - 0.109)	48 72	3.4 2.0	2.7
Dissostichus mawsoni	52	1033 ± 100 (214 - 4450)	0.040 ± 0.005 (0 - 0.245)	48 72	5.4 3.9	1.7
Cygnodraco mawsoni	197	299 ± 9 (25 - 1020)	0.019 ± 0.002 (0 - 0.245)	48 72	1.7 1.0	2.1
Gymnodraco acuticeps	84	413 ± 45 (160 - 780)	0.034 ± 0.004 (0 - 0.196)	48 72	5.7 4.4	2.0
Chionodraco hamatus	58	437 ± 38 (300 - 940)	0.021 ± 0.005 (0 - 0.11)	48 72	2.4 1.6	0.72
Cryodraco antarcticus	21	604 ± 85 (79 - 1300)	0.051 ± 0.01 (0 - 0.2)	48 72	4.2 2.25	0.7

1 the value following ± is the mean square error (σ)

2 minimum and maximam values

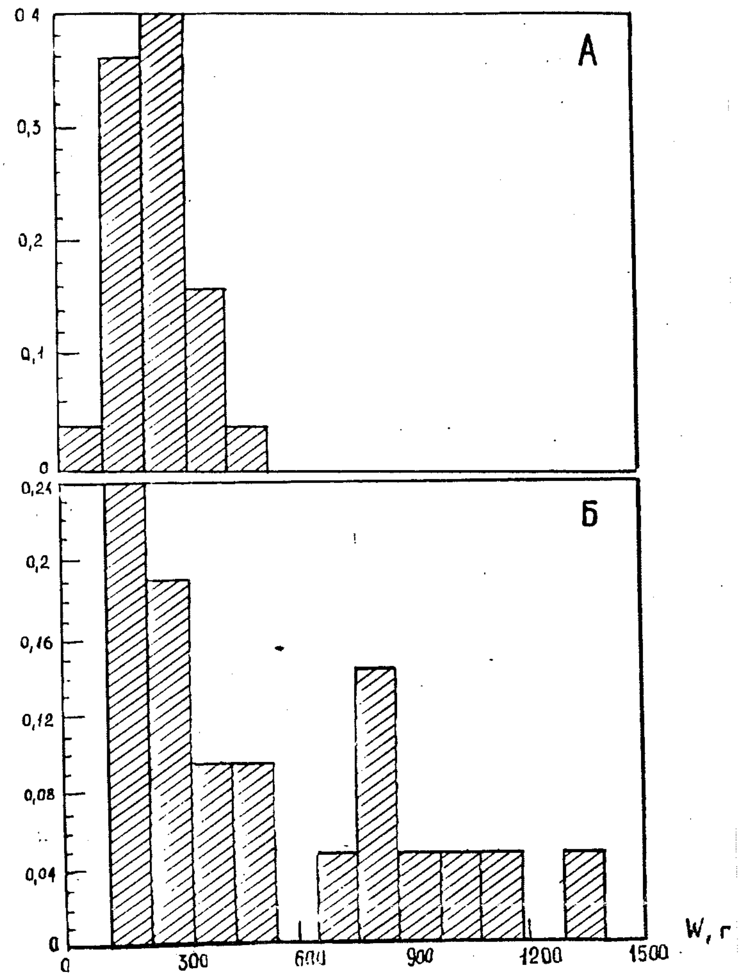

Figure 1: Weight frequency distribution of *Trematomus hansoni* in two consecutive samples: Sample A - mean weight 236 g; sample B - mean weight 524 g.

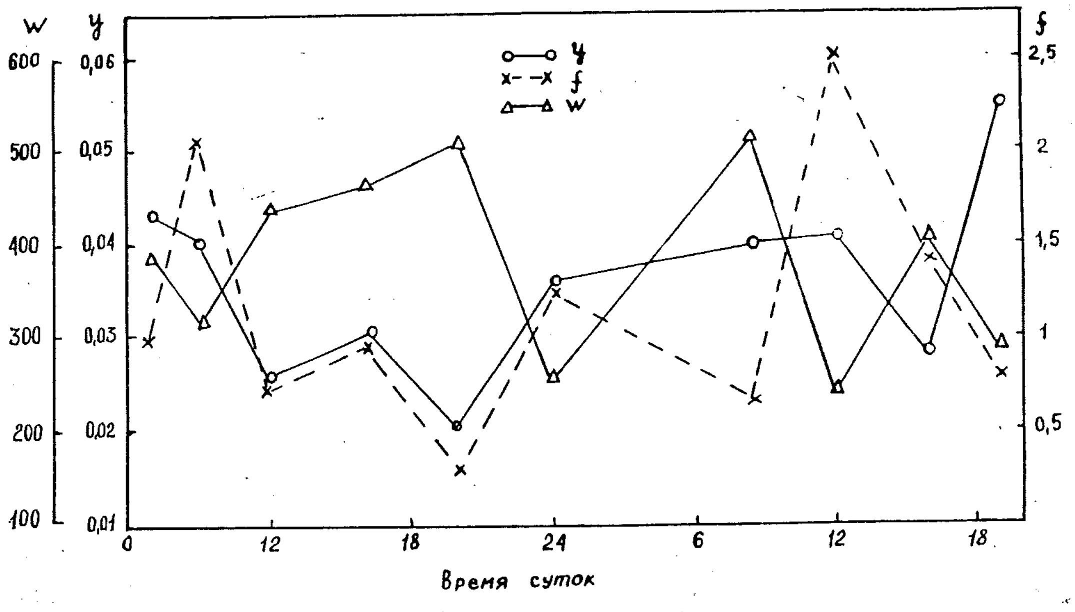

Figure 2: Mean values of the stomach fullness index (y), amount of fresh food (f) and body weight (W) for *Trematomus hansoni* from consecutive samples taken during a 36-hour station in the Kosmonavtov Sea on 23-24 March 1988.

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