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Parasitology

AN INFLUENCE OF THE PARASITE *CLAVELLA ADUNCA* (STRØM 1762)
(*COPEPODA PARASITICA: LERNAEOPODIDAE*) ON THE COD (*GADUS MORHUA* L.)
FROM NORTH-WEST ATLANTIC WATERS

WPŁYW PASOŻYTA *CLAVELLA ADUNCA* (STRØM, 1762) (*COPEPODA PARASITICA:*
LERNAEOPODIDAE) NA DORSZE (*GADUS MORHUA* L.)
Z WÓD PÓŁNOCNO-ZACHODNIEGO ATLANTYKU

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Over the years 1970 and 1974 there were carried out studies on the prevalence of the *Clavella adunca* (Strøm, 1762) parasite on the cod (*Gadus morhua* L.) from North-west Atlantic (Labrador and New Founland fishing grounds). The growth rate and condition of 4454 cod specimens was studied. The length-weight relationship, condition, and growth parameters of infested and non-infested fishes were calculated. The calculations have shown that young fishes infested by *Clavella adunca* parasite had higher average weight and condition than noninfested ones of the same length. On the other hand, older infested fishes (above 6 years of life) had average weight and condition lower than noninfested specimens. The author's own attempt to explain this paradoxal phenomenon is presented.

INTRODUCTION

Body build and development of the parasite *Clavella adunca* is recognized quite satisfactorily, on the other hand much less is known about incidence and intensity of parasitic invasion, and almost nothing about an influence of parasite on host. Only Poulsen (1939) in the years 1933–1936 carried off the studies on the prevalence of the parasite *Clavella adunca* on the cods from waters surrounding Denmark, and determined the condition for 300 fish specimens not finding any distinct differences between noninfested and infested cods. Many researchers from the later period of time refer to Poulsen's results in their statements about lack of influence of parasite on fish. However, they all agree that the parasite causes injuries of fish tissue which is distinctly visible on the gills.

Clavella adunca feeds up host's blood which is taken by a means of the mouth organ placed on the peripheral part of mobile cephalothorax. Action of the parasite on host's tissue has been thoroughly analysed by Kabata (1970) who stated that gill injuries may result from the way of parasite nutrition as well as by attachment and pressure exerted on the gills.

The aim of this work was an attempt of the determination of the parasite *Clavella adunca* influence on growth and condition of cods from Northwest Atlantic waters (Labrador and New Founland fishing grounds).

MATERIALS AND METHODS

Materials for survey were collected in the Labrador and New Foundland fishing grounds (region 2J and 3K accordingly to ICNAF¹) at 1970 and 1974 years. Research work has been done on the board of factory-trawlers belonging to Deep Sea Fishing Company "Dalmor". Totally, 4454 cod individuals have been subjected to detailed ichthyological analysis, out of this 2767 specimens at 1970, and 1687 at 1974.

Relationship between weight and length of fishes, condition, and parameters of growth of non-infested and infested fishes were studied in details for numerous variants. Because the most characteristic results were obtained for non-infested fishes and for fishes with infested gills, in this work only these results are presented.

Length and fish weight relationship was calculated by the use of Lagler's (1963) equation:

$$W = K \cdot L^n$$

where:

- W — fish weight
- L — length of fish
- K, n — constant coefficients calculated empirically.

¹ International Commission for Northwest Atlantic Fisheries

Condition of non-infested and infested fishes according to body length, age, sex, and the stage of gonads maturity was evaluated on the basis of the following formula:

$$K = \frac{W \times 100}{L^3}$$

where:

K — coefficient of the condition

W — weight of the fish

L — length of the fish

Growth parameters were calculated on the basis of average lengths of non-infested and infested fishes in the particular age groups by the use of von Bertalanffy's formula:

$$L_t = L_{\infty} (1 - e^{-K(t-t_0)})$$

where:

L_t — fish length in the age t

L_{∞} — asymptotic length

K — coefficient of catabolism

t — age of the fish

t_0 — the conventional beginning of the growth curve

e — base of the Naperian logarithm.

The mentioned calculations of length — weight relationship were partially made with use of Elliot 905 computer. In the detailed survey, the fishes infested by other gill parasite — *Lernaeocera branchialis* were not taken into consideration.

All calculations concern the actual state of the cod infestation in the moment of catch. For it is not possible to state how long the parasite was battenning on fish, as well as whether the fish being non-infested in the moment of catch, was not infested in the past.

The eventual influence of the internal parasites on fish was not taken into consideration in the survey.

THE RELATIONSHIP BETWEEN WEIGHT AND BODY LENGTH OF THE CODS NON-INFESTED AND INFESTED BY THE PARASITE

The calculations which were carried off only for fishes with infested gills have shown slightly greater differences in comparison with the fishes which besides parasite presence on the gills, additionally had the parasites on the other parts of body (on the fins, or close to anus). Because the number of fishes infested solely on the gills was minute, the fishes carrying the parasites on the other body parts were included in computations. Obtained results indicate that fishes with infested gills have larger weights initially than non-infested fishes of the same length (Fig. 1 and 2). At the body length 50 cm (1970), and 59 cm

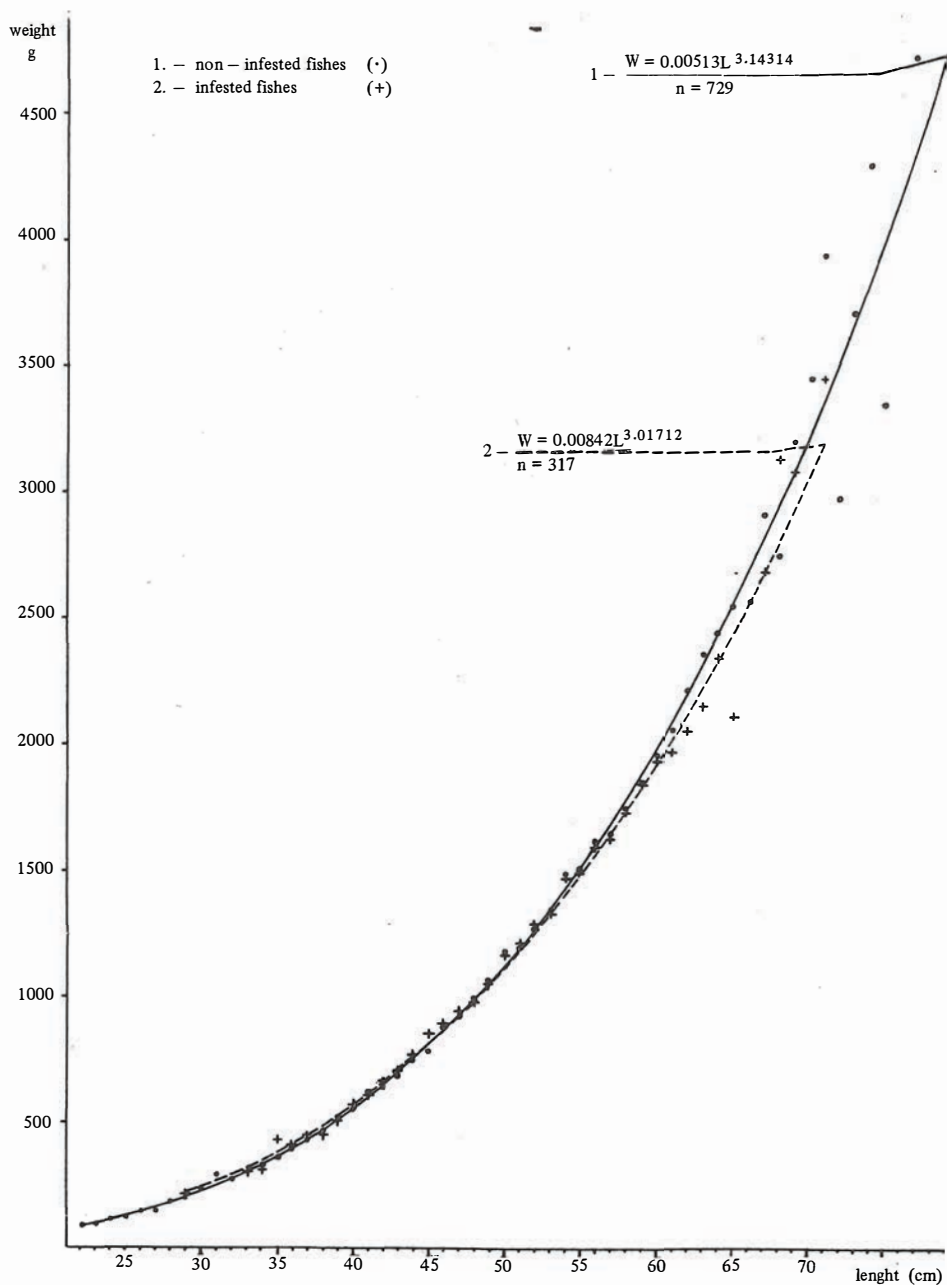


Fig.1. Weight-body length relationship of non-infested, and gill infested fishes, in region 2J and 3K at 1970. Points and asteriks represent average empirical weights for one centimeter length classes.

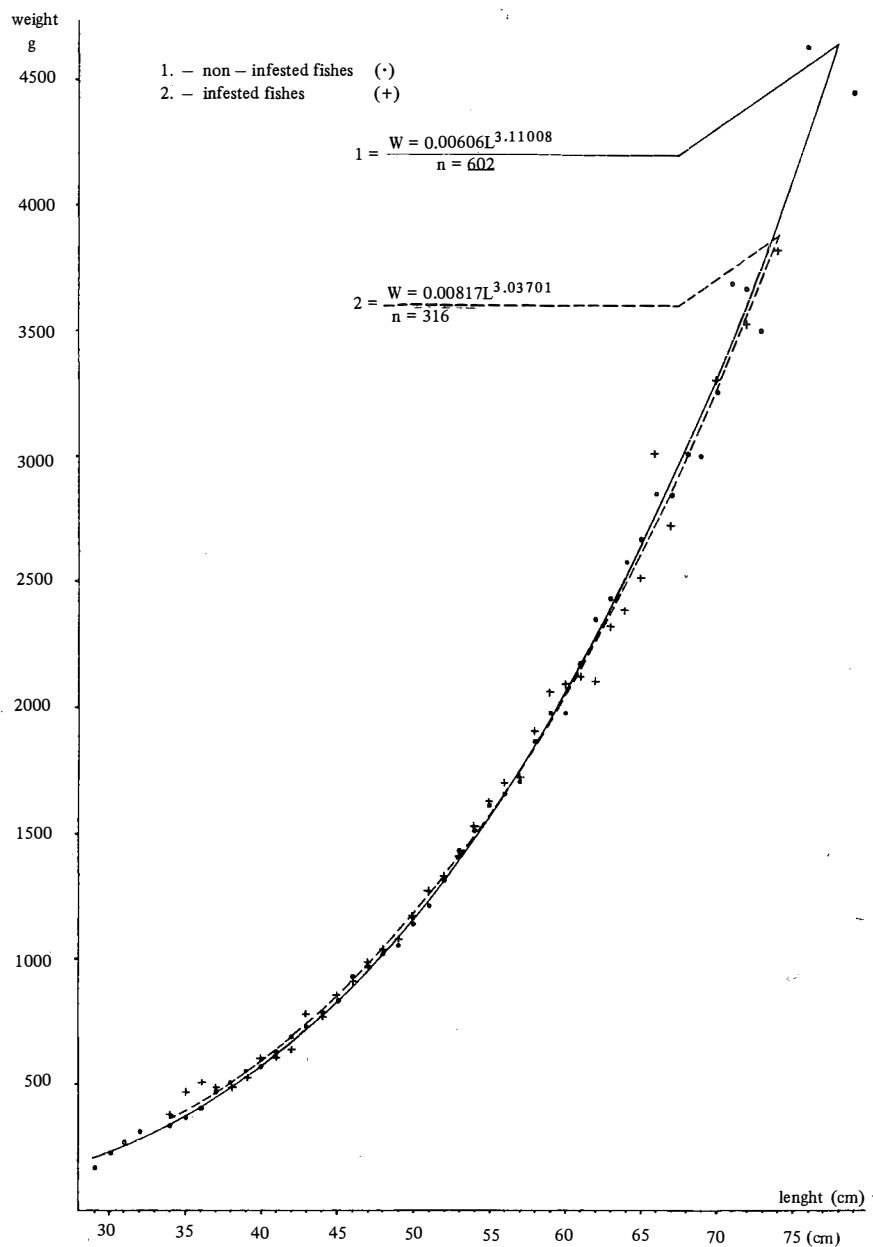


Fig. 2. Weight-body length relationship of non-infested, and gill infested fishes, in region 2J and 3K at 1974. Points and asteriks represent average empirical weights for one centimeter length classes.

(1974) weights of the fishes are identical, and with further increase of body length, the non-infested fishes are heavier than those infested.

The calculated K and n coefficients amount appropriately:

	year 1970	
non-infested fishes	K = 0.00513,	n = 3.14314
infested fishes	K = 0.00842,	n = 3.01712

	year 1974	
non-infested fishes	K = 0.00606,	n = 3.11008
infested fishes	K = 0.00817,	n = 3.03701

It could be noted from the data presented in Table 1 that the fishes infested by the parasite have different weights for the same lengths in comparison to non-infested fishes. Small cods of lengths from 30 to 35 cm are 5 to 7 percent heavier than non-infested fishes of the same length. For bigger fish (above 50 cm) those proportions are inverted — non-infested fishes are 1 to 4 per cent heavier than infested ones.

Table 1

Theoretical weights of non-infested and gill-infested cods
according to body length and year of catch in region 2J and 3K

Length (cm)	Years			
	1970	1970	1974	1974
	non infested fishes	infested fishes	non infested fishes	infested fishes
30	225	241	238	250
35	366	384	384	400
40	557	574	582	599
45	806	819	840	857
50	1 123	1 125	1 165	1 180
55	1 515	1 500	1 577	1 576
60	1 992	1 950	2 054	2 053
65	2 562	2 483	2 635	2 618
70	3 224	3 106	3 318	3 279
n	729	317	602	316
geometrical means:				
length (cm)	50.8	52.2	49.3	49.9
weight (g)	1 338	1 352	1 217	1 250

CONDITION OF NON-INFESTED AND INFESTED FISHES

Condition of the cods non-infested and infested by the parasite according to body length of fish

Condition coefficient has been calculated for non-infested and infested cods grouped into centimeter classes. Obtained results are shown on Fig. 3. In order to visualize more distinctly the changes, average K value was calculated and plotted for the three length classes e.g. up to 45 cm, from 46 to 60 cm, and above 60 cm.

The cods up to 45 cm of total length were sexually immature fishes, not spawning yet. The cods from 46 to 60 cm were representing mainly the fishes coming up to spawning, while all the fishes exceeding 60 cm represent part of population which spawns on the whole.

It proceeds from the distribution of the points and averages that condition of non-infested fishes increase with the body length. Such a regularity characterize the fishes caught up at 1970 and 1974 years. The condition of infested fishes initially also increases but for fishes exceeding 60 cm distinctly falls down.

It arises from the data presented on Fig. 3 that up to 45 cm of the body length the condition of infested fishes is better than of non-infested ones. In the length classes 46–60 cm average condition coefficients are similar, with condition being slightly better for non-infested fishes at 1970, and for infested fishes at 1974. This difference was probably resulting from the different length and age composition of the catches. Non infested fishes exceeding 60 cm of length represent much better condition than infested ones. This regularity existed in the both periods of survey.

Condition of non-infested and infested cods according to age of fish

So far the condition of the cods was considered in the complexion of fish length distribution. In order to check the changes of cod condition occurring with fish age, the condition coefficients have been calculated for the cods from particular age groups. The obtained results were used for graphical display of regression lines (Fig. 4). The results obtained when condition of fishes according to body length has been calculated, were confirmed. The infested cods from younger age groups had better condition than non-infested ones, while on the other hand, condition of older fishes were interior to the condition of non-infested fishes.

The regression lines for non-infested fishes could be expressed by the equation: $y = 0.0212x + 0.7864$ accompanied by the high value of correlation coefficient which equals 0.9139 (for fishes from 1970 year catches), and for non-infested fishes from 1974 year $y = 0.0224x + 0.8040$ with equally high value of the correlation coefficient 0.9404.

For the infested fishes: $y = -0.0074x + 0.9550$ (caught at 1970), and $y = 0.0010x + 0.9786$ (for the fishes caught up at 1974 year). In this case, the correlation coefficients were low and amounted -0.3714 and -0.1289 , respectively.

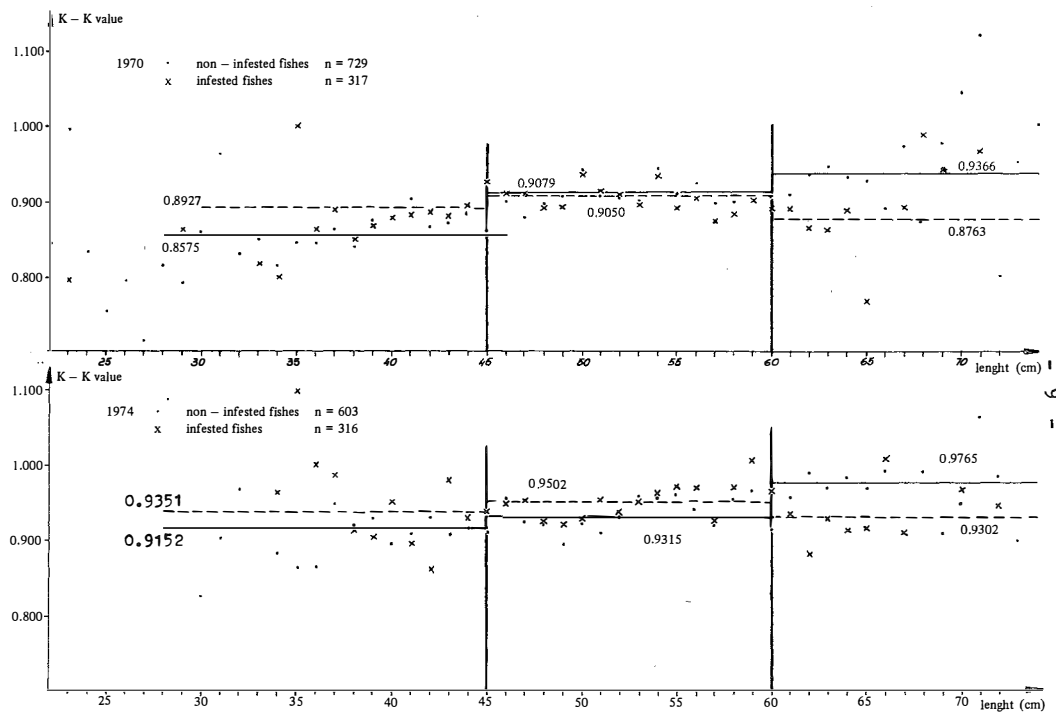


Fig. 3. Condition coefficient (K) in relation to the length of non-infested fish and gill-infested fish by the *Clavella* parasite in Labrador and New Foundland region, at 1970 and 1974. Horizontal lines represent average K value for different length classes, while points and asteriks represent average K value for the centimeter classes

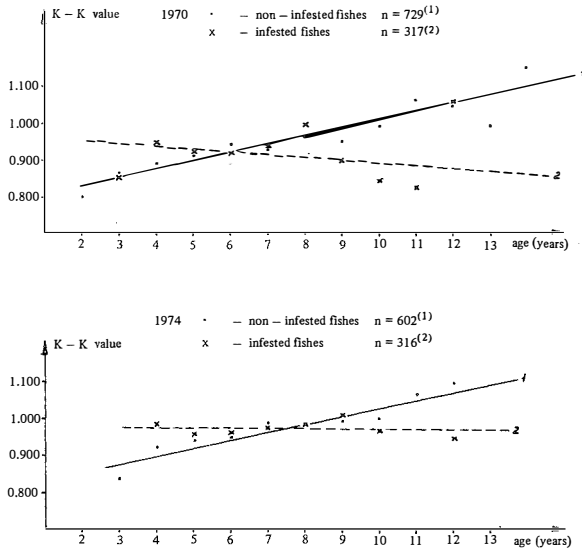


Fig. 4. Condition coefficient (K) in relation to the age of non-infested fish and infested fish by the *Clavella* parasite, in Labrador and New Foundland region, at 1970 and 1974. Points and asteriks represent average K values for the appropriate years of fish life.

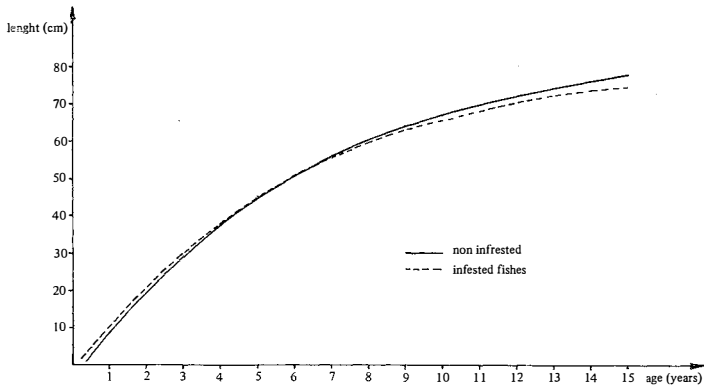


Fig. 5. Length increase curve of cods non-infested and gill infested by the *Clavella adunca* parasite, in the waters of Labrador and New Foundland at 1970 and 1974 (totally) calculated accordingly to von Bartalenffy's formula.

It proceeds from these calculations that condition of non-infested fishes was linearly increasing with their age, while the condition of infested fishes does not show such a regularity. The plotted straight lines representing infested fishes show exclusively tendencies in the condition changes according to the increase of fish age.

PARAMETERS OF THE INCREASE OF COD LENGTHS FOR NON-INFESTED AND INFESTED FISH ACCORDINGLY TO VON BERTALANFFY'S EQUATION

Because all previous surveys have shown that the same regularities and dependencies occur both in fishes from Labrador as well as New Founland waters, equally for 1970 and 1974 year, above computations were carried off for both annuals together. They were made with use of "ELLIOT 905" computer and obtained results for non-infested cods are shown in Table 2.

Table 2

Increase of the length of non-infested cods accordingly
to the von Bertalanffy's formula

Age of fish	Average empirical length	Frequency		Theoretical length	Difference between empirical and theoretical weight
		pcs.	per cent		
0	—	—	—	-4.39	—
1	—	—	—	8.59	—
2	26.00	4	3	19.73	6.27
3	29.50	25	19	29.30	0.20
4	37.50	77	57	37.51	-1.01
5	43.80	276	204	44.56	-0.76
6	51.10	445	329	50.61	0.49
7	55.60	335	248	55.80	-0.20
8	60.50	109	81	60.26	0.24
9	65.80	44	33	64.09	0.91
10	66.80	13	10	67.38	-0.58
11	69.60	11	8	70.20	-0.60
12	70.40	7	5	72.62	-2.22
13	72.80	5	4	74.70	-1.90
14	—	—	—	76.49	—
15	—	—	—	78.02	—
average empirical weight total	51.17	1351	1000		

The calculated parameters amount:

$$l_{\infty} = 87.31 \text{ cm}$$

$$K = 0.152595$$

$$t_0 = 0.3213$$

The length increase for the fishes with gills infested by the *Clavella adunca*, is shown in Table 3, and obtained parameters amount:

$$l_{\infty} = 81.55 \text{ cm}$$

$$K = 0.168670$$

$$t_0 = 0.1992$$

Table 3

Increase of the length of cods infested by the parasite
accordingly to the von Bertalanffy's formula

Age of fish	Average empirical length	Frequency		Theore- tical length	Difference between empirical and theoret- ical weight
		pcs.	per cent		
0	—	—	—	—2.79	—
1	—	—	—	10.30	—
2	—	—	—	21.36	—
3	30.00	1	2	30.70	—0.70
4	39.80	23	35	38.60	1.20
5	44.90	122	187	45.26	—0.36
6	50.80	265	407	50.89	—0.10
7	56.00	168	258	55.65	0.35
8	59.40	54	83	59.67	—0.27
9	64.30	13	20	63.07	1.23
10	62.20	4	6	65.94	—3.74
11	66.00	1	2	68.36	—2.36
12	—	—	—	70.41	—
13	—	—	—	72.14	—
14	—	—	—	73.60	—
15	—	—	—	74.83	—
average emp- irical weight total	51.69	651	1000		

The obtained results confirm the influence of the *Clavella adunca* parasite on the cods. The asymptotic length of non-infested fishes is 5.76 cm bigger than for infested fishes. Graphical display of growth curve of non-infested and infested fishes is shown on Fig. 5. Conclusion could be drawn from the curve that non-infested cods from younger age groups are growing slower than infested ones. Theoretical length of non-infested and infested cods in the age 6–7 years is approximate, and with the increase of the age, the length of non-infested fishes is bigger than of infested ones.

DISCUSSION

The determination of parasite influence upon growth and condition of fishes meets with a lot of difficulties, resulting mainly from the lack of possibilities to estimate the magnitude of losses suffered by fishes as a result of the infestation by parasite. The present status of knowledge does not permit for univocal determination of the parasite influence on fishes. It is especially difficult in the populations living in the natural marine environments.

An additional difficulty is created by the lack of possibility to establish whether presently non-infested fishes were non-infested in the past, and whether parasite-caused changes did not remain visible even after vanishing of parasites. The surveys conducted by Reichenbach-Klinke a.al. (1968) have shown that fishes suffer from the results of infestation through the longer period of time. However, it is not possible to determine the period of lasting of parasites on the fishes, and to state whether infestation has taken place the first time.

Usually, to determine the range of changes caused by the parasite presence, the comparisons are made between non-infested and infested fishes as to the body length, weight, condition, hemoglobine content in blood, and fat content of liver.

In the *Clavella adunca* case, irritation and destruction of the cod gill tissue results from the attachment of the parasite and its feeding. The tissue-ingrown bulla causes swelling of its while the mobile cephalothorax terminated by mouth organ which sometimes exceeds 4 mm destroys adjoining gill flakes.

The common opinion exists that as a result of parasite infestation general impairment of the organism takes place, connected with loss of body weight. The results of this work clearly indicate that young infested fishes weighed more than non-infested fishes of the same length. Average empirical weights and lengths of the young infested fishes (up to 6 years) were bigger than those of non-infested fishes. On the other hand, the older infested fishes had the average weights and lengths smaller than non-infested ones. The differences for the particular age groups were as follows (data from 1970):

Table 4

Condition of infected and non infected fishes

Fish age	Infestation	Number of fishes	Average length (cm)	Average weight (g)	Condition coefficient (K)	Per cent of loss or gain of weight
1	2	3	4	5	6	7
3*	non-infested	23	—	—	—	—
	infested	1	—	—	—	—
4	non-infested	61	36.6	434	0.885	(100)
	infested	14	39.3	577	0.951	+32.9

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1	2	3	4	5	6	7
5	non-infested	125	43.0	720	0.906	(100)
	infested	66	44.2	791	0.916	+ 9.9
6	non-infested	186	52.3	1 347	0.942	(100)
	infested	106	51.7	1 267	0.917	-5.9
7	non-infested	201	55.2	1 557	0.926	(100)
	infested	108	54.9	1 539	0.930	-1.2
8	non-infested	72	58.6	1 918	0.953	(100)
	infested	38	57.6	1 898	0.993	-1.1
9	non-infested	29	64.5	2 188	0.941	(100)
	infested	6	60.7	2 010	0.899	-8.1
10*	non-infested	10	—	—	—	—
	infested	3	—	—	—	—

* calculation were not carried off with regard to small number of fishes in the sample.

Similar regularities were also observed for the cods which were caught up at 1974.

Regarding the present state of knowledge it is impossible univocally interpret this phenomenon, and efforts of its explanation may be stressed as follows:

First concept — assumes an initial stimulating action of the parasite on fish, consequently causing an increase of food consumption and subsequent increase of the body weight. Kabata (1958) studied the haddock infested by the gill parasite *Lernaeocera obtusa* taking into consideration average lengths and weights of infested fish as well as hemoglobine level of the blood, and fat content in liver. His observations have shown that young fishes infested by the young parasite had bigger average weights, lengths, higher level of hemoglobine in the blood, and content of the liver fat. Kabata explains this as follows: an initial loss of blood by the fish is caused by the parasite, acts stimulative on the blood producing organs, and as a result of it, the hemoglobine level in blood is higher than normally. An increase of the hemoglobine level in the blood is connected with an increase of oxygen uptake which may cause enhancing of the feeding activity of fish. As a result, both fat liver content and weight of fish increases. In course of time, however, the activity of parasite increases as it grows up, blood losses are becoming larger, the hemoglobine content is decreasing which subsequently causes lessening of liver fat content and weight decrease.

The blood and cod liver were not studied in this work, however, lengths and weights of the fishes have shown similar interdependence as observed by Kabata. The observed rate of stomach filling of non-infested and infested fishes did not show distinct differences as to the quantity of taken food.

The consideration of this possible to accept hypothesis arises, however, some doubts, for example: why the parasite does stimulate only young fishes, and why 5–6 years old fishes have condition, average lengths and weights approximating these measures of

non-infested fishes, besides the fact of their maximal intensity and extensiveness of infestation.

Second concept – assumes higher mortality rate of the younger fishes of poor condition which are infested by parasite and that only fishes with best condition remain alive.

In the *Clavella adunca* case this concept does not seem proper for the parasite occurs not too numerously, and extent of the gill flake injuries caused by it is too small to treat this a serious weakening of the fish. The young fishes of exceptionally poor condition were not observed in the examined material.

Third concept – assumes the primary infestation of the young fishes which joined earlier the adult stock. Usually, those are the biggest individuals, born earlier, and in better condition. On the other hand, smaller fishes of weaker condition are joining the stock later, and shorter stay in it (before catch), and for this reason the possibilities of their contact with parasite are lower.

This concept founded on the biological basis seems to be the most probable explanation in this case. It is known that cods from Labrador and New Foundland region are spawning in the period of February – April. The conditions of an environment influencing hatch of fish larvae e.g. water temperature, salinity, and icing, are changing in this season. As early as during hatch, not all the fishes have identical condition, for an important role may play here the dimensions and qualitative changes in the eggs, causing divergences of an initial stage of fish growth. The features of an issue are formed by spawning ground, water temperature, nutrition, and vegetal period of the eggs and larvae. The young individuals are forming the juvenile school where the fishes out of the same annual represent differential condition and body length. The completion of the commercial stock by the juvenile fishes is usually beginning when they reach the age of 3 years. At this time, the fishes of the best condition are joining the adult school primarily, and there the majority of them is getting infested by the parasite. In course of time, the adults are joined by the fishes of weaker condition from the same age group which with respect to the shorter stay between mature fishes were not yet infested by the parasite. At the moment of catch, the fraction of fishes with better condition, remaining longer in the adult school is already infested, while on the other hand, the fishes which joined the stock just lately, have slightly weaker condition, and are not yet infested by the parasite.

This creates an impression as if the parasite would act on the young fishes in stimulative way, causing the acceleration of their growth.

In view of above discussed matter, the author agrees to an opinion that the parasite does not bring about an increase of young cods condition at all, but it exerts negative influence upon the fishes of each length and age. It is confirmed by the further analysis of the fish body growth where the fishes about 50 cm length have almost identical condition as non-infested ones, representing simultaneously the maximal rate of intensity and extensiveness of infestation. This is caused by slight but systematic weight loss of infested fishes. Above 60 cm of the fish length, it is already clearly visible, when condition of infested cods, and their average lengths and weights are definitely smaller than of non-infested fishes, besides the low intensity of infestation.

The real influence of the parasite upon fish is getting visible only between those annuals where recruitment does not act already, e.g. for the fishes more than 6 years old. The fishes out of younger annuals are continuously replenished from the juvenile school, and in connection with it, their rate of infestation and condition depends mainly on the magnitude and the time of recruitment.

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WPŁYW PASOŻYTA *CLAVELLA ADUNCA* (Strøm, 1762) COPPODA
PARASITICA: LERNAEOPODIDAE
NA DORSZE (*GADUS MORHUA* L.) Z WÓD PÓŁNOCNO-ZACHODNIEGO
ATLANTYKU

Streszczenie

W latach 1970 i 1974 w północno-zachodnim Atlantyku (łowiska Labradoru i Nowej Funlandii) przeprowadzono badania nad występowaniem na dorszach (*Gadus morhua* L.) pasożyta *Clavella adunca* (Strøm, 1762). Przebadano wzrost i kondycję 4454 osobników dorszy. W tym celu obliczono zależność pomiędzy długością a ciężarem ryb, kondycję oraz parametry wzrostu ryb nie zarażonych i zarażonych. Wszystkie te obliczenia wykazały, że ryby młode zarażone pasożytem *Clavella adunca* miały średnie ciężary i kondycję większą niż ryby nie zarażone tej samej długości. Natomiast u ryb starszych zarażonych (powyżej 6 roku życia) średnie ciężary i kondycja były mniejsze niż u ryb nie zarażonych.

W pracy przedstawiono własną próbę wytłumaczenia tego paradoksalnego zjawiska. Zakłada ona pierwotność zarażenia ryb młodych, które wcześniej dołączyły do stada dorosłego. Są to zwykle osobniki największe, wcześniej urodzone i o lepszej kondycji. Natomiast ryby mniejsze, o słabszej kondycji później uzupełniają stado dorosłe, przebywając w jego obrębie krócej (przed złowieniem) i wobec tego mają mniejsze możliwości zetknięcia się z pasożytem.

Rzeczywisty wpływ pasożyta na rybę uwidacznia się więc dopiero wśród tych roczników, na które nie działa już rekrutacja, czyli u dorszy powyżej 6 roku życia. Ryby młodszych roczników są ciągle uzupełniane ze stada młodocianego, w związku z czym ich stopień zarażenia i kondycja są w dużej mierze uzależnione od wielkości i czasu rekrutacji.

Ежи Януш

ВЛИЯНИЕ ПАРАЗИТА *CLAVELLA ADUNCA* (STROM, 1762)
(COPEPODA PARASITICA: LERNAEOPODIDAE) НА ТРЕСКУ (*GADUS*
MORHUA L. ИЗ СЕВЕРО-ЗАПАДНОЙ АТЛАНТИКИ

Резюме

В 1970 и 1974 годах в северо-западной Атлантике (районы лова: Лабрадор и Ньюфаундленд) исследовали заражение трески (*Gadus morhua* L.) паразитом *Clavella adunca* (Strom, 1762).

Исследовали возраст и состояние 4454 экз. трески. С этой целью подсчитали зависимость между длиной и весом рыб, их состояние а также параметры роста рыб зараженных и не зараженных. На основании подсчетов пришли к выводу, что молодые особи зараженные паразитом *Clavella adunca* имели больший средний вес и были в лучшем состоянии, чем рыбы не заражены, той же длины. Но у старших зараженных (свыше 6 лет), средний вес был меньшим и они находились в худшем состоянии чем рыбы не зараженные. В работе представлено попытку объяснения этого парадоксального явления. Она предполагает первичность заражения тех молодых рыб, которые раньше присоединились к взрослому стаду. Обычно это наибольшие особи раньше рожденные и в лучшем состоянии. Рыбы меньшие, в худшем состоянии более поздно пополняют взрослое стадо и ко времени вылова находятся в стаде более короткий срок. В связи с этим имеют меньшую возможность контакта с паразитом. Отчетливое влияние паразита на рыбу проявляется лишь только среди рыб тех возрастов, в которых уже не наблюдается пополнения стада т.е. у трески свыше 6-летнего возраста. Рыбы младших возрастов постоянно переходят из несовершеннолетнего стада к взрослому в связи с этим степень их заражения и состояние в большей мере зависят от величины и времени пополнения.

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