International Council for the Exploration of the Sea

C.M. 1980/F:4
Mariculture Committe

ANNUAL VARIATION OF FEEDING AND GROWTH RATE OF EELS FARMED IN THERMAL EFFLUENTS OF A CONVENTIONAL POWER STATION [1)]

by

H. Koops and H. Kuhlmann
Institut für Küsten - und Binnenfischerei
der Bundesforschungsanstalt für Fischerei
Palmaille 9, 2000 Hamburg 50

1. Abstract

Eel farming experiments are carried out in tanks of 12-50 m^2 at an experimental warm water station in Emden. The tanks are supplied with cooling water from a conventional power station. The eels are kept in running water (exchange rate once per hour) and fed with different types of industrial feeds (meal mixed with water).

Counting one tank for one control period as one experiment, altogether 73 single experiments have been done from 1975 until October 1978. For the calculation of the regression between growth rate and season the daily growth rate was assumed to be constant for the whole period, regardless of the time of an experiment (which varied between about 6 weeks and 5 months). These values have been grouped by months and for two groups of feeds. The average growth values were plotted against months. Both groups of feeds showed minimum growth rates in March/April and maximum values in August/September. Except for high summer conditions, under which both feed groups gave similar growth rates, Milkivit and an experimental diet were remarkably superior to Aalfi or wet food(chopped fish and shrimp). The correlation between daily growth rate and time of year could be described in form of a regression. The growth-curves are shifted compared with the temperature

1) This paper has been submitted also to the EIFAC-Symposium on new developments in the utilization of heated effluents and of recirculation systems for intensive aquaculture held from 28 May to 30 May 1980 in Stavanger.

curve by about six weeks, which partly may depend on the way of calculating the averages. The difference between these two feed groups becomes obvious comparing the calculated average weight of 40 g eels after 1.5 years of 210 g resp. 420 g.

2. INTRODUCTION

Eels and other euryhaline water fish are grown in an experimental farm of the institute at the warm water outlet of a conventional power station in Emden. The experiments are financially supported by the Federal Ministry for Research and Technology.
The experiments mainly deal with eels as the economically most interesting species. The eels were kept in fibre glass tanks of 6-8 m in diameter in densities of 5-10 kg/m^2 and fed with different types of feed. The paper tries to summarize results obtained from 1975-1978 and to demonstrate the season-related variation of the specific growth rate for different feeds fed.

3. INVESTIGATIONS PUBLISHED

Only few informations on the relation of growth rate to water temperature have been published. Honma (1971) reports on experiments of the Hamana-institute with farmed eels (Anguilla japonica) in Japan.

Table 1: Growth rate and feeding rate of Japanese eels in relation to water temperature

Period	Watertemp. °C	daily growth-rate %	daily feeding rate in % of body-weight (dry food)	feed conversion
25.02.-27.03.	11-22	1.72	6.55	3.80
22.11.-24.12.	19-22	1.04	2.38	2.30
03.10.-09.11.	20-22	0.20	0.41	2.03
30.08.-20.10.	19-25	1.13	1.58	1.40
07.04.-12.05.	22-24	0.42	0.64	1.50
08.06.-08.07.	23-28	1.04	2.39	1.18

The data in the table have been calculated by the data reported. For the interpretation one has to consider that eel culture in Japan tends more to a standing-water culture with relative low stocking-densities (1-2 kg/m^2) than to running-water culture and high stocking densities. The standing water culture with high standing crops of phytoplankton results in unstable chemical and physical water parameters. If the original data are correct, for example a feed conversion of 1.50 at a feeding rate of only 0.64% of body weight per day at temperatures between 22 and 24°C, is highly suspicious, if not natural food may have contributed to a high percentage to the nutrition of the fish. The feed conversion data (kg dry feed per kg wet weight gain) - and these are originally published data - indicate an improvement with raising temperatures. The season-depending feeding rate is indicated by the food per month expressed in % of the total annual food as reported for the commercial eel farms in the Shizuoka-Prefecture as follows:

Month:	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Food%:	0.4	4.7	11.6	11.6	13.6	21.0	19.8	12.4	4.4	-

In laboratory experiments for eel-fry (Anguilla anguilla) from 8-13 cm, Kuhlmann (1974) could clearly demonstrate that, if within the course of the experiment at any time the average weight of the eels of the different groups was plotted against the temperature at which they were kept, for each period at the same temperature of 26-27°C the optimal growth increment could be found and that this also was the temperature of the optimal feed conversion. At higher temperatur (up to 29°C) higher food levels were accepted, but at the same time the feed conversion became worse, and the growth rate decreased. At even higher temperatures also the feeding level decreased.

4. EXPERIMENTS AT THE EMDEN STATION

a. Methodology

The experimental facilities consist of up to 8 circular tanks of 6 to 8 m diameter. They are annually stocked with fingerlings of 30-40 g. The tanks are supplied with effluent water form the power-station, which is heated by about 8-10°C. Thus temperature normally fluctuates between 10-13°C in winter and up to 30°C

in summer. As Emden is located at the tidal area of the river Ems, the salinity fluctuates between 4-6 °/oo in rainy periods and 18-22 °/oo during dry periods.
The eels are kept in running water at an exchange rate of ~ once per hour and at a depth of about 0.5 m. The stocking density normally ranges between 5 and 10 kg per m^2. Further details are reported in previous publications of the authors (Kuhlmann, H. and Koops, H., 1978).

Newly stocked eels are first fed with wet food (minced fish, shrimp and liver), after 1-2 weeks this food is gradually replaced by dry food, a meal, which has to be mixed with water to a soft paste.
The following feeds have been tried:

wet food	(W)
Aalfi-eel-food	(A)
Milkivit eel-food	(Mi)

and an own experimental dry food, in the following named "M", which was developed in cooperation with the Munic Institut für Physiologie, physiologische Chemie und Ernährungsphysiologie

The following figures are based on the meal weight of the feeds (without added water), 3 parts wet food is assumed to equal 1 part dry food. Feed conversion figures are given as meal weight fed divided by wet weight gain of the eels (difference between quantity stocked and quantity harvested plus weight of dead fish and weight of eels which have been taken out in between). The specific growth rate is the calculated percentage of body weight by which the eels must grow each day to reach their average weight at the end of the experiment. The specific feeding rate is the product of the feed conversion and the specific growth rate.

In the following chapter those 4 types of feeds mentioned are compared; as the wet food and Aalfi resp. Milkivit and the experimental diet gave similar results, the data are combined in two groups. The eels of all stocking year-classes (1975-1978) were kept and fed from stocking until the end of 1978, after some weeks or months the eels were counted and weighed and silvereels were taken out. Each tank within two controls is regarded as 1 experiment and the growth-rate is assumed to have been constant for the whole period. This figure was used for each single month of a control-period, months overlapping the beginning or the end of an experiment were included, if the overlapping period was at least 10 days.

5. RESULTS

In table 2 all single month-data of all experiments carried out are listed. Experiments after first stocking are separated, they are related to summer months, as the stocking usually is done in May.

Table 2: Specific (daily) growth rate in % of body weight per day, grouped by feeds and months

Month	Feed									
January	A + W	-0.162	-0.162	0.106	0.126	0.187	0.280	0.379		
	Mi+ M	0.121	0.190	0.315	0.389	0.504	0.572			
February	A + W	-0.162	-0.162	0.106	0.126	0.187	0.280	0.379		
	Mi+ M	0.121	0.190	0.375	0.389	0.504	0.572			
March	A + W	-0.320	0.156	0.088	-0.016	-0.005	0.024	0.105	0.187	0.459 0.650
	Mi+ M	0.121	0.190	0.375	0.389	0.572				
April	A + W	-0.320	-0.156	-0.088	-0.016	-0.005	0.024	0.105	0.459	0.650
	Mi+ M	0.096	0.140	0.154	0.580					
May	A + W	-0.320	-0.156	-0.016	-0.005	0.024	0.105	0.389	0.394	0.794
	Mi+ M	0.096	0.140	0.154	0.580					
June	A + W	-0.320	-0.156	-0.016	0.105	0.389	0.394	0.794		
	Mi+ M	0.096	0.154	0.430	0.458	0.474	0.517	0.561	0.606	
July	A + W	0.389	0.394	0.794						
	Mi+ M	0.096	0.430	0.458	0.474	0.493	0.577	0.529	0.606	0.662 0.663
		0.845	0.850	0.954	1.001					
August	A + W	0.534	0.738	0.794	0.915					
	Mi+ M	0.430	0.458	0.474	0.493	0.517	0.529	0.561	0.606	0.623 0.662
		0.663	0.845	0.850	0.954	1.001				
Sept.	A + W	0.013	0.379	0.455	0.534	0.700	0.738	0.788	0.794	0.915
	Mi+ M	0.430	0.458	0.474	0.493	0.529	0.561	0.606	0.623	0.662 0.663
		0.845	0.850	0.954	1.001					
October	A + W	0.040	0.126	0.187	0.261	0.379	0.534	0.700	0.738	0.788 0.79
		0.915								
	Mi+ M	0.430	0.458	0.474	0.493	0.504	0.517	0.529	0.561	0.572 0.606
		0.623	0.662	0.837	0.954	1.001	1.048			
November	A + W	0.040	0.126	0.187	0.261	0.379	0.534	0.794	0.915	
	Mi+ M	0.315	0.474	0.504	0.517	0.561	0.572	0.837	1.048	
December	A + W	-0.162	-0.162	0.106	0.126	0.187	0.280	0.379	0.915	
	Mi+ M	0.315	0.375	0.389	0.471	0.504	0.536	0.572		
Initial stocking		-0.109	-0.183	-0.021	0.020	0.030	0.033	0.116	0.196	0.284 0.378
		0.448	0.501	0.551						

The arithmetic means per month are given in Table 3.

Table 3: Average specific growth rate grouped by months

Month	A + W			Mi + M			Total		
	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s
Jan.	7	0.1077	0.2063	7	0.3523	0.1604	14	0.2300	0.2182
Febr.	7	0.1077	0.2063	7	0.3523	0.1604	14	0.2300	0.2182
March	10	0.0840	0.2875	7	0.3523	0.1604	17	0.1945	0.2733
April	9	0.0726	0.3025	4	0.2425	0.2264	13	0.1248	0.2837
May	9	0.1343	0.3379	4	0.2425	0.2764	13	0.1639	0.3049
June	7	0.1700	0.3814	8	0.4120	0.1865	15	0.2991	0.7088
July	3	0.5257	0.2324	15	0.6093	0.2338	18	0.5953	0.2281
Aug.	4	0.7453	0.1590	15	0.6444	0.1846	19	0.6656	0.1803
Sept.	9	0.5907	0.2782	15	0.6444	0.1846	24	0.6243	0.2200
Okt.	11	0.4965	0.3099	17	0.6431	0.1968	28	0.5855	0.2527
Nov.	8	0.4045	0.3180	8	0.6035	0.2306	16	0.5040	0.2874
Dec.	8	0.2086	0.3434	7	0.4517	0.0942	15	0.3221	0.2802

These data allow to compute the relation between growth rate (y) and time (x) in form of a 4^{th} order regression ($y = A_o+A_1x+A_2x^2+A_3x^3+A_4x^4$) in which "x" is the number of feeding days since the 1st of January for 6 feeding days per week and 312 days per year respectively (for example the 15^{th} of January is day number 13, the 15^{th} of August day number 194). The calculated factors A_o-A_4 are given below.

Feed	A_o	A_1	A_2	A_3	A_4	r^2
A + W	0.254968	$-0.895950 \cdot 10^{-2}$	$0.997446 \cdot 10^{-4}$	$-0.228311 \cdot 10^{-6}$	$-0.294502 \cdot 10^{-10}$	0.8602
Mi+ M	0.446828	$-0.505146 \cdot 10^{-2}$	$0.379065 \cdot 10^{-4}$	$0.192154 \cdot 10^{-7}$	$-0.301864 \cdot 10^{-9}$	0.8781
Total	0.363742	$-0.779718 \cdot 10^{-2}$	$0.735661 \cdot 10^{-4}$	$-0.105652 \cdot 10^{-6}$	$-0.188053 \cdot 10^{-9}$	0.8840

The single controls are not equally distributed over the year and probably the total curve therefore may be shifted by about one month. This however will not - or only little - change the statement, that the growth of the eels drastically was influenced by the type of food used and that the calculated average weight after 1.5 years of feeding differs by about 100%.

By this regression-growth rate and time - it is possible to calculate the theoretical growth of eels under the Emden conditions as it is done in table 4 and figure 1.

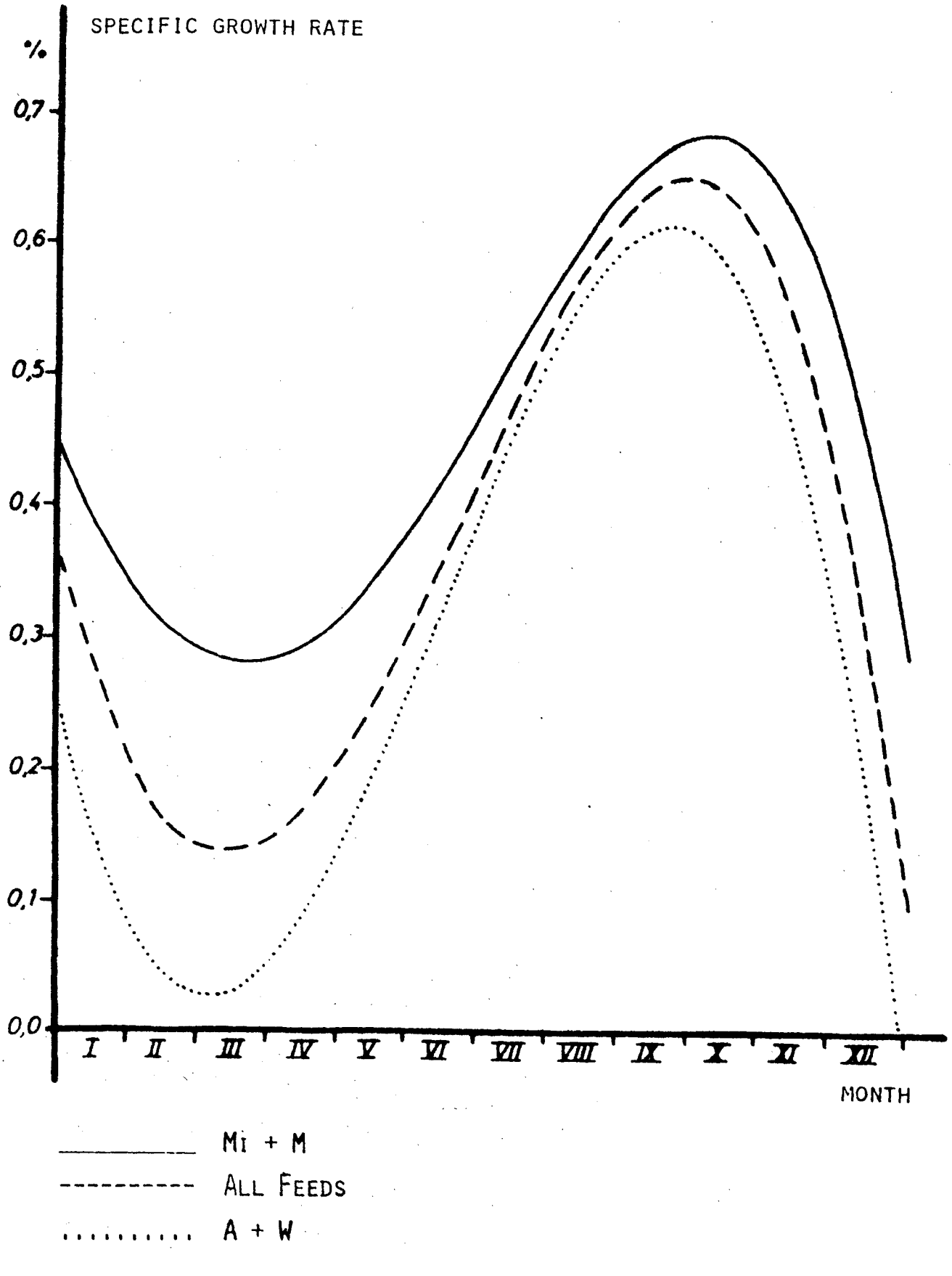
Table 4: Computed growth of farmed eels in Emden

Date	$\bar{x}$g for A + W	$\bar{x}$g for Mi + M	$\bar{x}$g for both feed groups
1. July	40.00	40.00	40.00
1. August	44.96	45.69	45.21
1. September	52.54	53.73	52.48
1. October	61.52	63.84	61.93
1. November	71.39	76.05	73.01
1. December	79.87	89.07	83.86
1. January	83.13	99.99	91.00
1. February	86.58	110.57	97.74
1. March	87.59	119.12	101.79
1. April	88.33	128.13	105.50
1. May	90.39	138.31	110.24
1. June	95.08	151.31	117.63
1. July	103.47	168.16	129.11
1. August	116.44	192.10	146.10
1. September	134.58	224.46	169.75
1. October	157.55	268.36	200.37
1. November	182.99	319.73	236.09
1. December	205.79	374.45	270.73
1. January	214.25	420.35	292.50

In this model the eels would have been stocked about at the beginning of June with an average weight of 40 g. The first week is needed for adaptation without growth, the calculation starts with the 1st of July (day number 154) as the first feeding day. The actual growth situation differs somewhat from this model as the individual growth of the eels differs considerably. Already in November and March quite a good number

FIG. 1

COMPUTED GROWTH OF FARMED EELS IN EMDEN



of eels will have reached weights of 250-400 g and are sorted out to be sold. On the other hand males do not grow larger than 180 g and have to be taken out when silvering. Part of the males already silver in the first winter. The calculations above are based on the results until end of 1978. It has to be mentioned that in the meantime the feeding management has been improved by optimizing the feeding levels and the oxygen-situation in the tanks and in summer and autumn 1979 growth rates of 0.9-1% of body weight per feeding day have been achieved regulary at stocking densities up to 15 kg/m^2.

6. SUMMARY

In an experimental eel farm supplied with heated brackish water from the Emden power station eels are fed in circular tanks of 6-8 m in diameter. Stocking densities varied between 5 and 10 kg per m^2. Several times a year the eels have been counted and weighed. The single results of these controls for 1975-1978 have been used for computing a growth model of the eels for different types of feeds used.
The importance of adequate feeds are demonstrated by the fact that depending on the feed quality resp. the type of food, the average weights after 1.5 years farming differ by 100% (50%) (about 210 resp. 420 g). The computed regression refers to months, not to temperatures and is greatly smoothed as the daily growth rate was taken to be constant over a whole control period.

In 1979 considerable progress has been made in the feeding technique and summer growth rates have been improved to 0.9-1% of bodyweight per day. The relation growth rate-temperature based on daily temperatures and feeding levels will be calculated soon, when sufficient data are available.

7. REFERENCES

Honma, A., 1971 : Aquaculture in Japan. Japan FAO Association, Tokyo

Kuhlmann, H., 1974 : Experimentelle Untersuchungen über den Einfluß von Wassertemperatur und qualitativem Futterangebot auf das Wachstum und die Geschlechtsdifferenzierung des Europäischen Aales. Dissertation im Fachbereich Biologie der Universität Hamburg

Kuhlmann, H., und Koops, H., 1978 : The silvering of eels cultured under warm water conditions. ICES C.M. 1978, F:8, Mariculture Committee