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ON THE EXPERIMENTAL FEEDING OF SEA BREAM (*SPARUS AURATA* L.) UNDER AQUARIUM CONDITIONS

O EKSPERIMENTALNOM HRANJENJU KOMARČE (*SPARUS AURATA* L.) U AKVARIJSKIM UVJETIMA

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Young sea bream (*Sparus aurata* L.) from the mid-Adriatic coastal waters were kept in aquaria and fed on artificial and natural food. Comparative experimental feeding was carried out to contribute to our knowledge of their nutrition in captivity having in view their more efficient rearing.

Observations were carried out in an open circulation system (constant seawater flow). Environmental conditions were similar to those at the sea surface in the vicinity of the Institute.

Artificial food used in this experiment was composed of fish meal, and wheat flour to which brewer's yeast and vitamin mix were added. Hen egg was also added as a binding agent. Sardine were used as primary natural food, and when sardine were lacking, mussel or squid.

Food consumption, growth in length and weight as well as their relation to temperature were studied in two fish groups.

Conversion factor, weight-length relationship and condition factor were calculated for both groups. Growth coefficient was graphically obtained.

INTRODUCTION

Sea bream (*Sparus aurata* L.) belong to the sparidae family. They are widely distributed in the Mediterranean and Atlantic, particularly in the lagoonar lakes of Italy, France, Tunisia, Egypt and Israel.

Sea bream are widely distributed in the Adriatic, as well, inhabiting inshore waters, particularly those close to river mouths. Sea bream is a species of high market value, highly priced all over the world. However, this fish are landed in very small quantities.

Even though the attempts to rear sea bream can be traced back even to ancient times (ancient Rome and Greece), studies of their biology and ecology were not started until recently. Earlier studies of sea bream ecology in the Adriatic were mainly limited to their adult stages (Syrski, 1876; Lorini, 1902). Ranzi (1930), Pasquali (1941), D'Ancona (1941), Audouin (1960, 1962) and Lasserre (1972, 1974, 1975, 1976) published papers dealing with all the stages of sea bream from the Mediterranean. Various aspects of sea bream food and feeding habits were intensively studied. More recent works have included some systematic studies of the food of juvenile stages of *Crysophrys major* from Japanese waters, Furuichi and Yone (1971), Shitanda et al. (1971), Takeda and Yone (1971), Yone et al. (1971) and Yone and Fujii (1974, 1975). These were the first attempts to study the effects of prepared diets on marine fish growth. This had been studied for years on freshwater fish. Their results provided a significant ground for studies of marine fish feeding in general. However, this problem requires further studies, particularly for the purpose of intensive culture of this valuable species. Having this in mind, an experimental comparative feeding of sea bream under aquarium conditions was carried out in our laboratory. We hope that our work may provide a further step in the development of sea bream culture.

MATERIAL AND METHODS

Juveniles were caught along the north-eastern coast of the Kaštela Bay on April 23, 1975. Small trawl net of 11 m length, 3.5 m highest depth and 4 mm mesh size was used. Fish were impounded at 0.1—0.6 m depths on sandy-muddy bottom overgrown by *Zosterela noltii.*

Sea bream total length varied from 1.85—2.82 cm, 2.39 mean length. Their weight ranged from 0.050—0.202 g, 0.128 g mean weight.

Fish were kept in the 210 l aquarium basin for three months. Preliminary observations of their response to different food, their feeding habits and time, as well of their behaviour under aquarium conditions were carried out over this period.

By June 3, 1975 sea bream had attained the mean total length of 4.6 cm.

Twenty four surviving sea bream were used for a comparative feeding study which commenced on July 29, 1975. One group (A) of fish was offered artificial food and the other group (B) natural food. At the beginning of the experiment fish mean total length was 10.3 cm and mean weight 15.2 g.

Fish were kept in 230 l rectangular concrete tanks with the continuous water replacement system. The lowest recorded rate of water flow was 2.5 l/min.

Water temperature was measured every day during fish feeding. It varied from 10.6—23.5°C. Salinity varied from 34.6—38.1‰. Weekly mean sea water temperature ranged within 11.4 and 23.2°C. Fig. 1 presents the variations of weekly mean temperatures.

Oxygen content (4.04—6.25 ml/l) was somewhat lower (for about 0.5 ml/l) in the aquarium than in the sea water of the Kaštela Bay (4.37—6.87 ml/l).

Benzokain anaesthetized fish were measured for total length and weighed every 30 day. Experiment was completed on May 11, 1976. All fish survived.

Food

Artificial food

Formulation of artificial food is given in Table 1.

Table 1. Artificial diet formulation

Dry part	60—65%	
Fish meal		69%
Wheat flour of 400 type		15%
Brewer's yeast		14%
Vitamin mix		2%
Wet part	40—35%	
Egg		100%

Food was sieved to a particle size range of 2.5—4.0 mm dependently of fish size. The binder was hen egg white which increases the stability of granules in the sea water.

Artificial food composition and nutritive value are given in Table 2.

Table 2. Composition and nutritive value of artificial food (»dry« and »wet« parts in percentages)

Food components	Dry part — Wet part (60—40%)	Dry part — Wet part (65—35%)
Proteins	34.7	36.6
Carbohydrates	10.7	11.5
Fats	8.9	8.7
Moist	34.9	31.7
Ashes	9.5	10.3
Vitamins	1.2	1.3
KJ/100 g	1118	1152

Fish meal contained mainly proteins and fats and wheat flour contained carbohydrates. Diets contained high percentage of moist (32—35%).

Fish meal from Peru was not always of the same chemical composition. Thus, proteins varied from 60—65%, fats from 6—12%, moist from 8.5—11.5%. It contained about 18.8% of ashes. That's why artificial food composition varied (proteins from 34—38%).

Artificial food recalculated to dry matter contained 16747 KJ/kg. This recalculation was based on caloric values of 37.7 KJ/g for fats, 17.2 KJ/g for proteins and 17.2 KJ/g for carbohydrates.

Natural food

Natural food contained sardines, mussels and squids. Mussels and squids were used only when there were no sardine. Muscle tissues of sardine were only used as food.

Chemical composition of sardine *Sardina pilchardus* (Walb.) muscle tissues are given in Table 3. It is shown that this composition varied much in the course of the year. Fat percentage varied most (0.9—8.7%) and proteins somewhat less (15.6—23.5%).

Table 3. Composition and nutritive value of natural food

Food components	Sardines* Min.	Sardines* Max.	Sardines* Mean	Mussels** Min.	Mussels** Max.	Mussels** Mean	Squids***
Proteins	15.6	23.5	21.1	8.9	17.2	12.0	18.0
Carbohydrates	—	—	—	—	4.3	1.8	0.3
Fats	0.9	8.7	4.6	1.1	4.0	2.1	1.2
Moist	64.7	74.5	69.4	68.6	83.9	77.8	77.5
Ashes	1.7	5.2	4.8	1.7	2.9	2.3	3.0
KJ/100 g	388	692	537	194	520	316	352

* Krvarić-Škare (1955)
** Marinković-Roje (1968)
*** Brodarec (1976)

Natural food contained less proteins, fats and carbohydrates than artificial food. Fish probably compensated this shortage by taking greater food quantities.

Mean moist level was 69.4% in sardine, and 77.5% in mussels and squids (Table 3).

Due to the high moist level of natural food its caloric value was lower than artificial food caloric value. It varied from 3877—6921 KJ/kg in sardine, from 1942 — 5204 KJ/kg in mussels and about 3516 KJ/kg in squid. Sea bream probably compensated their energetic requirements by taking greater quantities of natural food.

Feeding

Fish were fed three times daily and twice a day in winter. Food was supplied as long as fish took it. Therefore food losses were very low. Feeding lasted not more than half an hour. Each meal was weighed.

RESULTS AND DISCUSSION

Food consumption

Quantities of food consumed per week by two different fish groups are given in Fig. 1 together with weekly mean temperature variations. Artificial food consumption per week (A group) varied from 18.1—242.2 g. Respective values of weekly natural food consumption (B group) were considerably higher, ranging between 74.1 and 437.9 g.

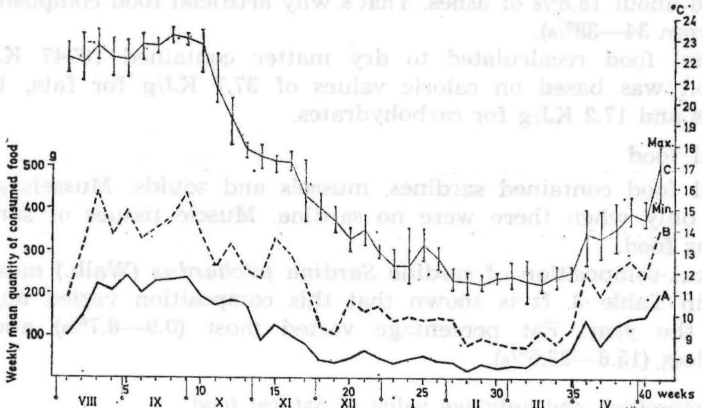

Fig. 1 Weekly mean consumption of artificial (A) and natural (B) food and weekly mean sea water temperature (C)

Quantities of food consumed per week in summer considerably exceeded those in winter.

Weekly mean consumption of artificial food throughout the experiment was 110.2 g for 12 fishes (9.2 per individual) and weekly mean natural food consumption 222.8 g (18.6 per individual).

Data on monthly mean artificial and natural food consumption for two sea bream groups are given in Tables 4 and 5, together with some other data. Monthly mean artificial and natural food consumption variations showed the correlation with temperature variations (Fig. 1). Quantity of consumed food increased with temperature increase. The analysis showed that this correlation was statistically significant ($p < 0.01$) (Fig. 2).

Dependence of food consumption on temperature could be expected since the sea bream are poikilothermous organisms.

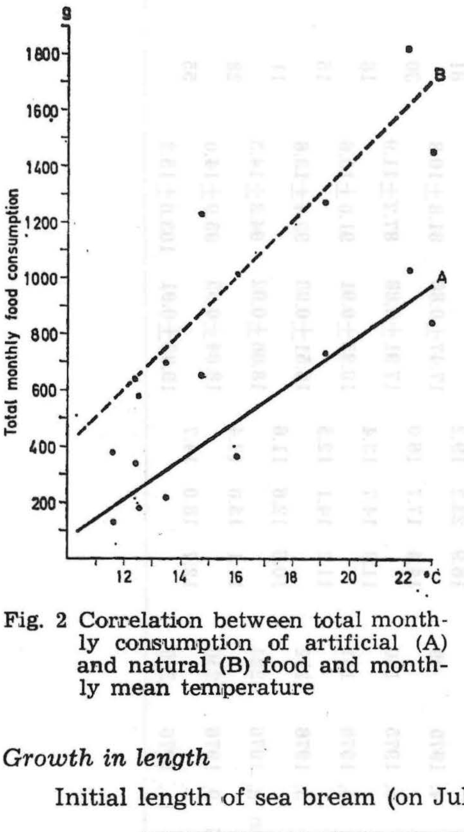

Fig. 2 Correlation between total monthly consumption of artificial (A) and natural (B) food and monthly mean temperature

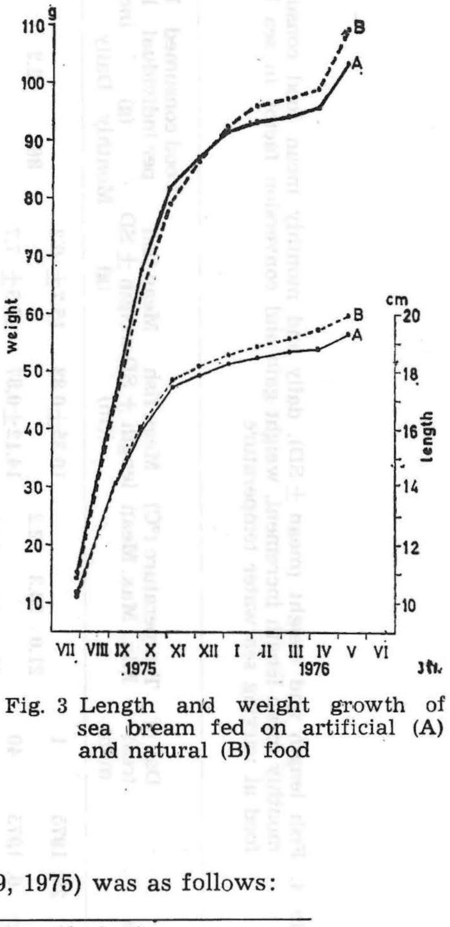

Fig. 3 Length and weight growth of sea bream fed on artificial (A) and natural (B) food

Growth in length

Initial length of sea bream (on July 29, 1975) was as follows:

	Length (cm)			
	Minimum	Maximum	Mean	SD
A group	8.7	11.9	10.4	± 0.83
B group	7.8	11.9	10.3	± 1.16

The growth in length is given in Fig. 3. Fish from both groups showed best growth during the first months, what, in fact, was expected. For the first three months (August, September and October) juvenile fish mean length

Table 4. Fish length and weight (mean ± SD), daily and monthly mean food consumption per individual, monthly mean length increment, weight gain and conversion factor in sea bream fed od artificial food at varying sea water temperature

Date	Day of treat-ment	Temperature (°C) Min.	Max.	Mean	Mean fish length ± SD (cm)	Mean fish weigth ± SD (g)	Food consumed per individual (g) Monthly	Daily	Mean length increment (cm)	Mean weight gain (g)	Conver-sion factor
July 29, 1975	1				10.35±0.83	15.7± 6.2					
		21.0	23.3	22.2			86	2.2	3.77	29.9	2.9
Sept. 6, 1975	40				14.12±0.87	45.5± 7.7					
		22.3	23.5	23.0			71	2.6	1.84	22.2	3.2
Oct. 3, 1975	67				15.96±0.86	67.7± 9.8					
		16.9	23.2	19.2			61	1.9	1.5	14.2	4.3
Nov. 4, 1975	99				17.47±0.86	81.8±10.8					
		14.4	17.7	16.0			30	1.0	0.44	5.3	5.7
Dec. 5, 1975	130				17.91±0.88	87.2±11.9					
		11.8	14.7	13.4			18	0.6	0.34	4.6	4.0
Jan. 5, 1976	161				18.25±0.91	91.8±13.6					
		11.2	14.1	12.5			15	0.5	0.26	1.7	9.1
Feb. 5, 1976	192				18.51±0.93	93.4±13.6					
		10.6	12.6	11.6			11	0.3	0.15	0.8	13.0
March 8, 1976	224				18.66±0.92	94.3±14.3					
		11.1	15.0	12.4			28	0.9	0.18	1.7	16.9
April 9, 1976	256				18.84±0.95	95.9±14.0					
		12.7	18.0	14.7			55	1.7	0.48	7.7	7.1
May 11, 1976	288				19.32±0.91	103.6±15.2					

increment was 7.3 cm (10.3—17.6 cm). For the succeeding months (November, December) growth was considerably slowed down to be quite poor during winter months (January, February, March). In spring fish growth was accelerated even though it was poorer than during the juvenile stage (Fig. 3).

Table 5. Fish length and weight (mean ± SD), daily and monthly mean food consumption per individual, monthly mean length increment, weight gain and conversion factor in sea bream fed on natural food at varying sea water temperature

Date	Day of treatment	Temperature (°C) Min.	Max.	Mean	Mean fish length ± SD (cm)	Mean fish weigth ± SD (g)	Food consumed per individual (g) Monthly	Daily	Mean length increment (cm)	Mean weight gain (g)	Conversion factor
July 29, 1975	1				10.28±1.16	14.6± 5.6					
		21.0	23.3	22.2			152	3.9	3.85	29.5	5.1
Sept. 6, 1975	40				14.13±1.06	44.1± 8.8					
		22.3	23.5	23.0			121	4.5	1.94	19.7	6.2
Oct. 3, 1975	67				16.07±1.12	63.8±11.4					
		16.9	23.2	19.2			107	3.3	1.67	15.6	6.8
Nov. 4, 1975	99				17.73±1.14	79.3±14.2					
		14.4	17.7	16.0			85	2.7	0.50	7.3	11.6
Dec. 5, 1975	130				18.23±1.16	86.7±15.3					
		11.8	14.7	13.4			59	1.9	0.36	6.0	9.8
Jan. 5, 1976	161				18.59±1.21	92.7±18.4					
		11.2	14.1	12.5			49	1.6	0.32	3.7	13.3
Feb. 5, 1976	192				18.91±1.25	96.3±20.3					
		10.6	12.6	11.6			32	1.0	0.26	1.0	32.0
March 8, 1976	224				19.17±1.24	97.3±21.7					
		11.1	15.0	12.4			54	1.7	0.34	1.8	30.5
April 9, 1976	256				19.51±1.34	99.1±22.9					
		12.7	18.0	14.7			103	3.2	0.48	10.5	9.8
May 11, 1976	288				19.99±1.32	109.6±24.4					

Differences in mean lengths between fish fed on artificial food and fish fed on natural food were very small. Growth in length was almost identical in both groups for the first three months (August, September, October). Later on (November, December) B group fish showed somewhat higher mean lengths. These differences increased from one month to the next to reach 0.67 cm at the termination of experiment (May 11, 1976).

Total sea bream length at the termination of experiment was:

	Length (cm)			
	Minimum	Maximum	Mean	SD
A group	17.5	21.0	19.3	± 0.91
B group	17.3	21.8	20.0	± 1.32

Total length growth for both sea bream groups averaged 9.4 cm (10.3—19.7 cm) and 1 cm/month.

Sea bream growth during the observation period may be taken as the first year growth, taking into account that the growth in December—May was quite insignificant.

Since there is no data on sea bream growth under natural conditions in the Adriatic our data were compared with the data from the Mediterranean.

Heldt (1943, 1948) studied the growth in length of sea bream from the lagoons and sea water along the coast of Tunisia. Considerable differences in length were observed between a year old sea bream from lagoons (21—27 cm) and those from the sea (14—16 cm). Heldt belived that these differences were due to considerably higher food quantities in lagoons and therefore poorer competition as well as to the smaller number of predators.

Audouin (1962) recorded the following length in a year old sea bream from the Thau lagoon on the southern coast of France:

1956 — 20 cm (15—23 cm)
1957 — 20 cm (15—23 cm)
1958 — 21 cm (16—24 cm)

Audouin (1962) found that sea bream from the Thau lagoon attained 4—6 cm in length at the beginning of May. In July their length was almost doubled (the smallest fish were seven cm long and the biggest 12 cm; mean length of nine cm was attained by 50% of this fish). From July to September sea bream growth rate was higher and in September their length ranged between 16 and 21 cm and 38% of fish attained mean length of 18 cm. In October when fish schooled and prepared for an offshore migration their mean length was 21 cm. Audouin also found that the growth rate differred from one area to another.

Lasserre and Labourg (1974a, b) and Lasserre (1976) studied the length of a year old sea bream from French lagoons and the sea in the vicinity of Sète. They found that during the first year of life the growth rate of sea bream from some of the lagoons (Thau, for example) (20—30 cm) considerably exceeded that of sea bream from the marine environment (18 cm).

Arias (1976) reported that sea bream juveniles of about 2 cm in length entered the lagoons in the vicinity of Cádiz (southern Spain) somewhere between January and March and attained the 24.4 cm length in November. Our fish were about 18 cm at that time.

Suau and López (1976) established that a year old sea bream from the marine environment of the Gulf of Alfaques at the Ebro delta (Spain) measured about 17 cm in length.

The foregoing data indicate that the growth rate of sea bream from the Mediterranean lagoons along the coast of France, Spain and Tunisia is much in excess of the growth rate of sea bream from the Mediterranean Sea. In some areas the length differences may even exceed 5—8 cm at the end of the first year of age. Our year old sea bream showed similar or even higher lengths than those from the Mediterranean Sea.

Weight gain

During the observation period sea bream showed particularly intensive weight gain, that is their mean weight increased from the initial 0.13 g to 15.7 g (A group) and 14.6 g (B group) respectively.

Initial weight of sea bream on July 29, 1975 was as follows:

	Weight (g)			
	Minimum	Maximum	Mean	SD
A group	8.0	26.0	15.7	± 6.2
B group	7.0	22.0	14.6	± 5.6

Fish gained intensively in weight for the first three months (from July 29 to November 4, 1975). Their weight gain averaged 65 g (A group 66.2 g, B group 64.8 g). At the beginning of autumn their weight gain rate was lowered. This continued up to the beginning of spring when fish began to gain in weight again, however much less than in the juvenile stage. Over the six month period, from the beginning of November to the termination of experiment fish gained in weight not more than 25 g (A group 21.8 g, B group 30.2 g).

Differences in mean weight between these two groups were very small (Fig. 3). At the beginning of experiment the differences between fish selected at random was 1.1 g in favour of the A group to be increased during the succeeding months. In December 1975 the curves crossed. In January 1976 A group mean weight was somewhat lower than the B group one. Further on, the difference in weight increased in favour of the B group to reach 6 g at the termination of experiment. The change of the relation between curves took place while sea bream growth rate was low.

Koenig (1974) also found that sea bream fed on natural food showed pretty good weight gain in winter (growth was not controlled later). However, these fish were kept at constant temperature of 20°C.

Similarity between the weight gain of our both groups proves that the artificial food used was quite appropriate.

At the termination of experiment sea bream weighed:

	Weight (g)			
	Minimum	Maximum	Mean	SD
A group	74	133	103.6	± 15.2
B group	65	151	109.6	± 24.4

Total weight gain was 87.9 g in A group and 95.0 g in B group. Monthly weight gain per individual averaged 9.3 g for A group and 10.1 g for B group.

Since no data on sea bream growth rate under natural conditions were available for the Adriatic, our data were compared with the data from the Mediterranean.

Heldt (1943, 1948) found that during the first year of life the weight gain (about 200 g) of sea bream from Tunisian lagoons was faster than that of sea bream from the marine environment of the Mediterranean sea along the coast of Tunisia. This was explained by the larger food quantities available in lagoons, poorer competition and smaller number of predators.

Audouin (1962) recorded mean weight of 1.5 g in sea bream from the Thau lagoon. In July their size was almost doubled (the smallest individuals weighed 4 g and the biggest 22 g; 50% of fish attained mean weight of 8 g). Between September and July fish showed significant gain in weight. In September 38% of sea bream attained 85 g. In October, when fish were schooling and preparing for an offshore migration 38% of fish weighed approximatively 120 g.

At the end of the first year of age sea bream from the lagoons Bages and Palavas showed different weight values. Audouin (1962) reported that sea bream from the Bages lagoon gained in weight more slowly than those from the Thau lagoon and those from the Palavas lagoon showed approximatively the same growth rate as those from the Thau lagoon (85—155 g; mean weight 120 g). This author concluded that different localities showed different rate of weight gain.

Lasserre and Labourg (1974a) and Lasserre (1976) observed that during the first year of life growth in weight of sea bream from lagoon Thau and the bay of Arcachon (130—150 g) considerably exceeded growth in weight of sea bream from the sea round Sète (about 100 g).

Higher weight values were also recorded in sea bream from Spanish lagoons in the vicinity of Cádiz than in sea bream from the Mediterranean sea. Arias (1976) found that sea bream juveniles which entered lagoons between January and March weighed on the average 1 g and in November when they left lagoons they weighed on the average about 211.8 g. Suau and López (1976) reported the weight of 70—80 g for a year old sea bream from the marine environment of the Alfaques Bay in Ebro estuary.

Weight gain rate of sea bream from our feeding experiment was considerably lower than that of sea bream from lagoonar lakes along the shores of western Mediterranean. However, it was quite similar to the weight gain rate reported for sea bream living under natural conditions along the western Mediterranean coast (Lasserre and Labourg, 1974a; Lasserre 1976; Suau and López, 1976).

Dependence of length and weight increment on temperature

Length and weight of both sea bream groups increased with temperature. Parabolic relation was observed between sea bream length increment and temperature, (Fig. 4).

The same relation was found between weight gain and temperature (Fig. 5). Length and weight increment showed the dependence on monthly mean temperature throughout the experiment with the only exception at 23°C.

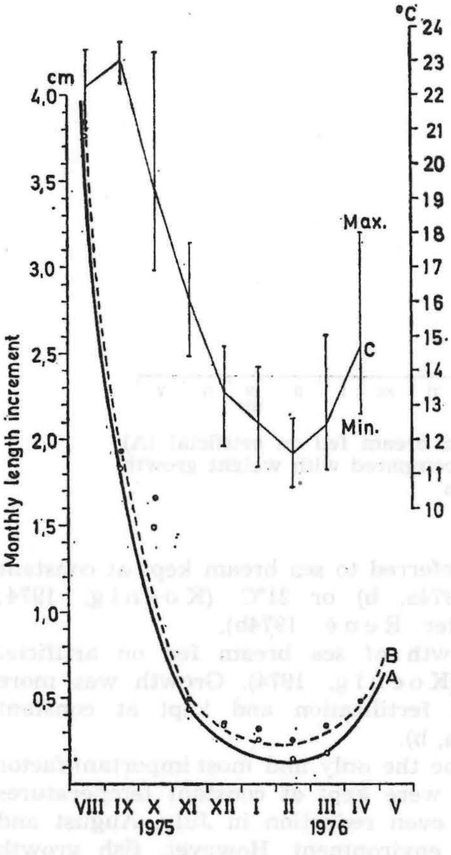

Fig. 4 Correlation between monthly mean (total) length increment and monthly mean temperatures (C) in sea bream fed on artificial (A) and natural (B) food

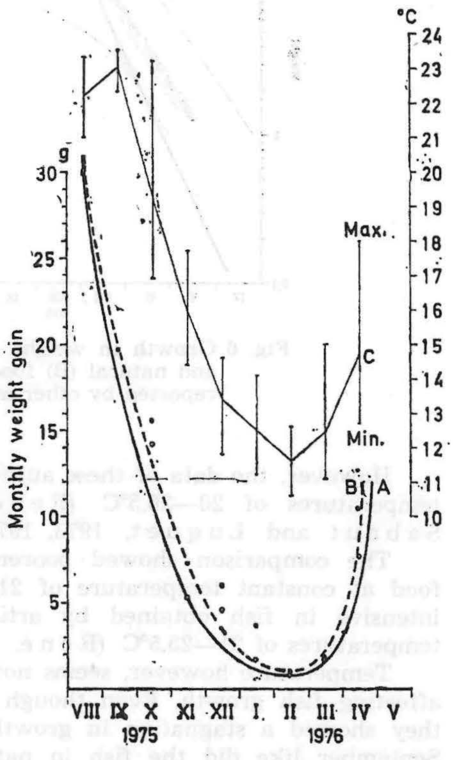

Fig. 5 Correlation between monthly mean weight gain and monthly mean temperature (C) in sea bream fed on artificial (A) and natural (B) food

Best growth in both length and weight was recorded at 22°C (Figs. 4 and 5).

However, it should be pointed out that since at that time (August 1975) fish were relatively small (14.1 cm) they showed the tendency of intensive growth.

It was attempted to compare our data on sea bream growth rate and increment under aquarium conditions with those for sea bream from the coastal area of southern France given by René (1974a, b), Koenig (1974), Sabaut and Luquet (1973, 1974, after René, 1974 b) (Fig. 6).

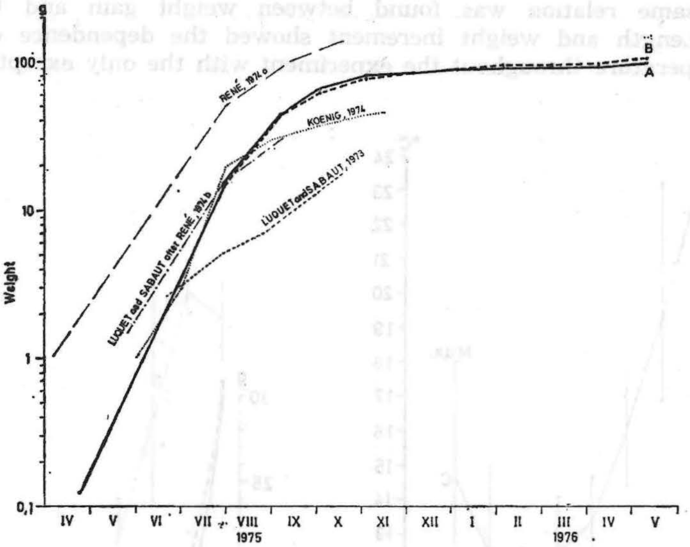

Fig. 6 Growth in weight of sea bream fed on artificial (A) and natural (B) food as compared with weight growth reported by other authors

However, the data of these authors referred to sea bream kept at constant temperatures of 20—26.5°C (René, 1974a, b) or 21°C (Koenig, 1974; Sabaut and Luquet, 1973, 1974 after René, 1974b).

The comparison showed poorer growth of sea bream fed on artificial food at constant temperature of 21°C (Koenig, 1974). Growth was more intensive in fish obtained by artificial fertilization and kept at constant temperatures of 21—25.5°C (René, 1974a, b).

Temperature however, seems not to be the only and most important factor affecting fish growth. Even though fish were kept at constant temperatures they showed a stagnation in growth or even reduction in July, August and September like did the fish in natural environment. However, fish growth could also be affected by different food they were offered by different authors. Sea bream growth, therefore, seems to be affected by other factors as well.

Fig. 6 also shows considerable curve brakes at the beginning of August. René (1974a) and Koenig (1974) held this due to the shorter photoperiod.

The conversion factor

The conversion factor (g of food per g of fish) was calculated according to the formula:

$$S_k = a/b$$

where a = monthly (wet) food consumption in grams
and b = monthly growth increment in grams

Monthly values of the conversion factor recorded in sea bream fed on artificial food (A group) ranged between 2.9 and 16.9, and in those fed on natural food (B group) between 5.1 and 32.0 (Tables 4 and 5). Values obtained in fish fed on natural food considerably exceeded those obtained in fish fed on artificial food.

The factor of food conversion was in both groups considerably lower in the warmer part of the year (2.9—4.3 and 5.1—6.8 respectively) than in the colder part of the year (4.0—16.9 and 9.8—32.0 respectively). The lowest values were recorded for both groups in August and September 1975 and the highest in February and March 1976.

The conversion factor (G) as influenced by temperature (T) may be well approximated by a hyperbola:

$$G = \frac{C}{T - t_0}$$

where C and t_0 are the constants.

As shown by Fig. 7 conversion factor values hyperbolically increase with temperature decrease.

For the thorough period of experiment the conversion factor vas 4.3 for fish fed on artificial food and 8.0 for fish fed on natural food.

In conversion factor observations it should be taken into account that moist was not extracted from our artificial food.

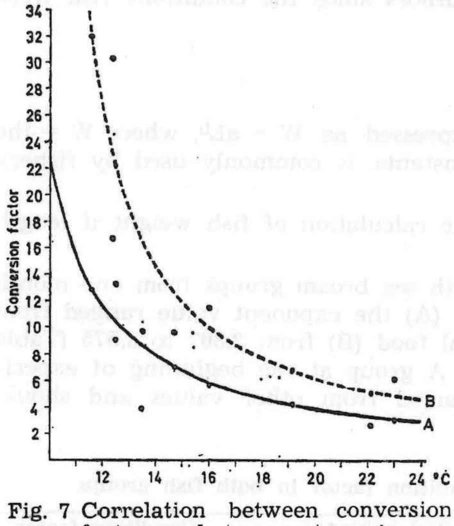

Fig. 7 Correlation between conversion factor and temperature in sea bream fed on artificial (A) and natural (B) food

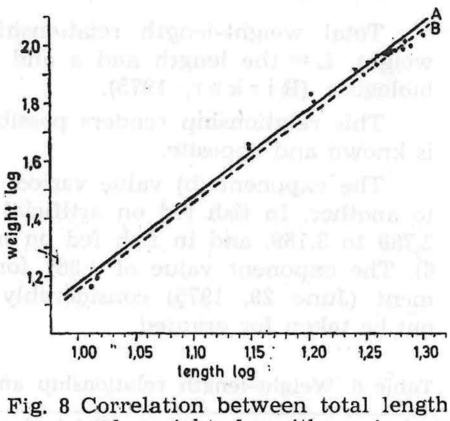

Fig. 8 Correlation between total length and weight logarithms in sea bream fed on artificial (A) and natural (B) food

The conversion factor values reported by René (1974a) for juvenile sea bream obtained by artificial fertilization and fed on artificial dry food were considerably lower and varied from 1.8 to 6.0. The conversion factor values recorded by René in the warmer part of the year (May — September) were lower (1.8 — 2.8) than those recorded in the colder part of the year (January — April). This difference reached as high value as 6.0 although fish were constantly kept at 20°C temperature, and from June to the end of September at still higher temperatures.

Sabaut and Luquet (1973) found that the conversion factor in young sea bream decreased with the increase of the percentage level of proteins in food. These authors established that 40% of proteins was the optimum level. In the course of four months their fish showed very low conversion factor (1.7). In preparation of food these authors used ready-made components, and the conversion factor was recalculated to dry matter. During the experiments fish were kept at constant temperature (21°C) indispensable for successful growth.

In our experiment, however, fish were kept at the temperature of the sea in the vicinity of our laboratory (about 10.5—23.5°C in dependence of the season). When moist (32—37%) was extracted from our artificial food by a mathematical calculation and the conversion factor recalculated to dry matter for temperatures exceeding 21°C, very low conversion factor was obtained (1.93). However, this value was still higher than that reported by Sabaut and Luquet (1.7). This difference in conversion factor may be directly dependent on the higher food protein level which was 40% in Sabaut and Luquet, not exceeding 34—37% in our experiment.

Thus corrected conversion factor values which were almost equal to the values reported by the above cited authors, show that our artificial food satisfied all fish feeding requirements. However, these values are not fully comparable with the values of other authors since the conditions fish were kept under and food fish fed on differed.

Weight-length relationship

Total weight-length relationship expressed as $W = aL^b$, where W = the weight, L = the length and a and b constants, is commonly used by fishery biologists (Ricker, 1975).

This relationship renders possible the calculation of fish weight if length is known and opposite.

The exponent (b) value varied in both sea bream groups from one month to another. In fish fed on artificial food (A) the exponent value ranged from 2.789 to 3.169, and in fish fed on natural food (B) from 2.867 to 3.575 (Table 6). The exponent value of 4.867 for the A group at the beginning of experiment (June 29, 1975) considerably departed from other values and should not be taken for granted.

Table 6. Weight-length relationship and condition factor in both fish groups

Date	Weight-length relationship*		Condition factor	
	Group A	Group B	Group A	Group B
July 29, 1975	$W = 0.0002\ L^{4.867}$	$W = 0.0057\ L^{3.345}$	1.41	1.34
Sept. 6, 1975	$W = 0.0213\ L^{2.893}$	$W = 0.0136\ L^{3.047}$	1.62	1.56
Oct. 4, 1975	$W = 0.0288\ L^{2.800}$	$W = 0.0220\ L^{2.867}$	1.67	1.54
Nov. 4, 1975	$W = 0.0279\ L^{2.789}$	$W = 0.0204\ L^{2.870}$	1.53	1.42
Dec. 5, 1975	$W = 0.0221\ L^{2.867}$	$W = 0.0162\ L^{2.954}$	1.51	1.43
Jan. 5, 1976	$W = 0.0129\ L^{3.052}$	$W = 0.0081\ L^{3.194}$	1.51	1.44
Feb. 5, 1976	$W = 0.0149\ L^{2.993}$	$W = 0.0054\ L^{3.328}$	1.47	1.43
March 8, 1976	$W = 0.0089\ L^{3.165}$	$W = 0.0025\ L^{3.575}$	1.45	1.38
April 9, 1976	$W = 0.0179\ L^{2.922}$	$W = 0.0032\ L^{3.474}$	1.43	1.33
May 11, 1976	$W = 0.0086\ L^{3.169}$	$W = 0.0029\ L^{3.515}$	1.44	1.37

* Values were calculated from mean lengths and weights given in Tables 4 and 5.

Between the beginning of September 1975 and the beginning of January 1976 exponent values were similar for both groups. On the contrary, later on individuals fed on artificial food showed the values which were lower than those in individuals fed on natural food (Table 6).

Weight-length relationship was calculated both for the group fed on artificial food and for that fed on natural food (Fig. 8). Monthly means were used. Correlation between length and weight logarithms was statistically significant ($p < 0.01$) for both groups.

$$\text{A group} \quad W = 0.0144 \quad L^{3.014}$$
$$\text{B group} \quad W = 0.0148 \quad L^{2.987}$$

Exponent values for both groups are very similar to each other and very close to the figure of 3.000 thus that it was concluded that sea bream showed isometric growth during the first year of life.

Weight-length relationship calculated by Amanieu and Lasserre (1973) for juvenile sea bream of 3.86—7.12 cm in length and 0.58—4.38 g weight captured in the Prévost Lake in May and June 1972 gave the following regression:

$$W = 0.0066 \; L^{3.286}$$

The exponent values these authors obtained were sligtly higher than ours.

Similar exponent values were also obtained for older sea bream (I—V age groups) caught from the sea round Sète $W = 0.0186\,L^{2.959}$ (Lasserre and Labourg, 1974a; Lasserre, 1976) and brackish water area of Arcachon $W = 0.0144\,L^{3.075}$, lagoon Thau $W = 0.0226\,L^{2.886}$ (Lasserre and Labourg, 1974a; Lasserre, 1976) and Spanish Peninsula $W = 0.0127\,L^{3.055}$ (Suau and López, 1976); $W = 0.0098\,L^{3.120}$ (Arias, 1976).

Condition factor

Estimation of fish condition is commonly based on the weight-length relationship. Fulton's condition factor $K_c = W/L^3$ is often used. Greater the fish weight at determined length the condition factor is greater and fish is in better condition.

The following function was used for sea bream condition factor calculation

$$K_c = 100 \cdot \frac{W}{L^3}$$

where W is the weight in grams and L length in centimetres.

Sea bream were mainly in good condition as shown by monthly mean condition factor values which ranged from 1.33—1.67, give in Table 6.

Condition factor values of fish fed on artificial food (A) differed from that of fish fed on natural food (B). Monthly mean condition factor of A group ranged from 1.41 to 1.67 and that of B group from 1.33 to 1.56.

Values of A group considerably exceeded the values of B group, for 0.04—0.13. The greatest differences were recorded in October-December 1975 and April 1976.

Minimum condition factor (1.41) was found in fish fed on artificial food at the end of July (the beginning of experiment) and the maximum one (1.67) in October. The respective values of 1.33 and 1.56 were recorded in fish fed on natural food in September 1975 and April 1976.

Monthly mean condition factor values showed an increase at the end of July — beginning of September period and/or October 1975 and stagnation from the beginning of November 1975 to the middle of May 1976 (Fig. 9).

Maximum values of condition factor (September, October) coincided with the maximum food consumption (Fig. 1) and the low values found in winter coincided with the reduced food intake. Maximum condition factor values, however, did not coincide with the maximum weight gain of fish (Fig. 5).

The condition factor values for sea bream could not be compared with the values for sea bream from the natural environment of the eastern Adriatic coast due to the difficulties in collection of the material. The data for sea bream from the southern coast of France (Lasserre, 1972, 1976) found in literature showed poorer fish condition (K_c = 1.20—1.42). Relatively high values of condition factor (1.41 in the lagoonar lake Thau and 1.42 in the sea close to Sète) were recorded in September, October and May, and the low ones in November (1.29), January and March (1.20). In December, February and April no observations were carried out. Condition factor values for sea bream from our experiment showed an increase in the March (1.20) — May (1.38) period (Fig. 9).

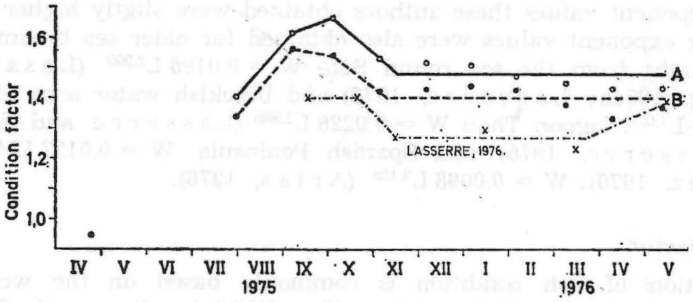

Fig. 9 Variations of condition factor in sea bream during our experimental feeding and variations of condition factor established by Lasserre (1976)

Linear growth — growth coefficent

The growth coefficient (K) was obtained graphically by von Bertalanffy's equation (1934, 1938) (Ricker, 1975):

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

where L_∞ = the ultimate length that an average fish would achieve if it continued to live and grow

K = the growth coefficient or the Brody growth coefficient

t_0 = hypothetical age for L_t = 0

The obtained data were graphically treated by transformed form of von Bertalanffy's equation (Ford/Walford plots) where t = 1:

$$l_{t+1} = L^\infty \ (1 - e^{-K}) + l_t e^{-K}$$

The growth coefficient values were taken from tables. Mentioned method was applied to the calculation of the growth coefficient of 0^{+} — I^{+} year class of both experimental groups (Fig. 10).

Group A	Group B
K = 0.285	K = 0.269

The growth coefficient values showed that A group fish grew faster than B group fish.

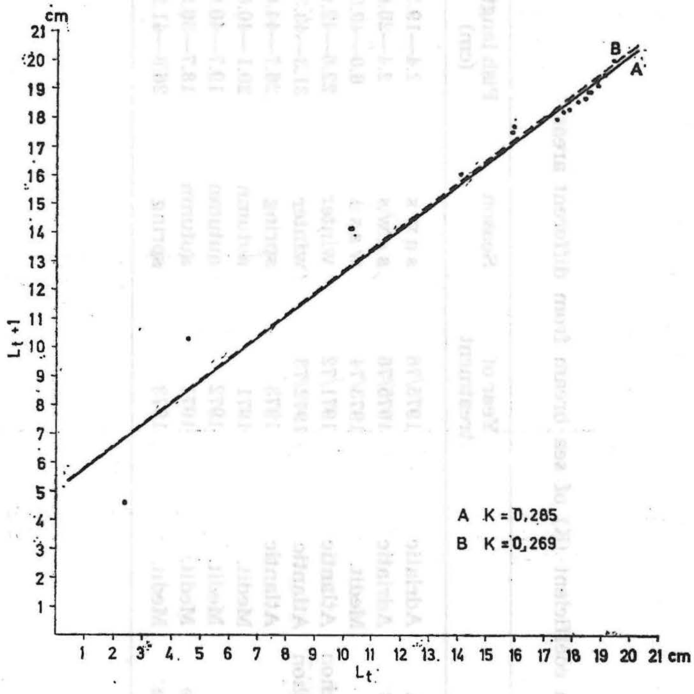

Fig. 10 Growth coefficient (graphically calculated after Walford, 1956) in sea bream fed on artificial (A) and natural (B) food

Data on the coefficient of sea bream growth were relatively scarce in literature until recently. Thus Lasserre (1974, 1976) and Lasserre and Labourg (1974a) studied the linear growth parameters for age II—V of sea bream from different locations of the Atlantic and Mediterranean coast of France and Suau and López (1976) for seven age groups of sea bream from the Mediterranean coast of Spain (Table 7).

Table 7. Growth coefficient (K) of sea bream from different areas

Study area		Year of treatment	Season	Fish length (cm)	Age	Growth coefficient (K)
Aquarium — A	Adriatic	1975/76	s a w s	2.4—19.3	0+—I+	0.285
Aquarium — B	Adriatic	1975/76	s a w s	2.4—20.0	0+—I+	0.269
Alfaques Bay	Medit.	1973/74	w s s a	6.0—49.0	I —VII	0.171
Region D'Arcachon	Atlantic	1971/72	winter	22.6—42.9	II —V	0.456
Region D'Arcachon	Atlantic	1972/73	winter	31.3—43.3	II —V	0.264
Gascogne	Atlantic	1973	spring	26.7—44.6	II —V	0.265
Thau lagoon	Medit.	1971	autumn	20.1—40.6	II —V	0.221
Thau lagoon	Medit.	1972	autumn	19.7—40.9	II —V	0.272
Vicinity of Sète	Medit.	1971	autumn	18.7—36.9	II —V	0.372
Vicinity of Sète	Medit.	1973	spring	26.8—41.2	II —V	0.256

Values of the growth coefficient reported for sea bream from the Atlantic coastal lagoons differed from those reported for sea bream from the Mediterranean coastal lagoons as well as from those for sea bream from the marine environment round Sète and Alfaques Bay. Individual locations also showed differences between spring and autumn values as well as year-to-year differences.

The values of growth coefficient we obtained could not be compared to the growth coefficient values reported for sea bream from the natural environment owing to different ages of fish studied (age 0^{+} — I^{+} in our experiment and I—VII and II—V respectively in the studies of the above cited authors).

The growth coefficient we obtained in both A and B groups was similar to those for the fish from the Mediterranean locations round Sète, D'Arcachon, Gascogne and Thau lagoon. The growth coefficient reported by Lasserre (1976) for D'Arcachon was considerably higher and that reported by Suau and López (1976) considerably lower than ours.

As shown by the results the growth coefficent was similar to that of fish from natural environment. Both the artificial and natural food proved efficient even though artificial food gave slightly better results than natural food.

CONCLUSIONS

Comparative experimental feeding of young sea bream by artificial (A group) and natural food (B group) under aquarium conditions showed the following:

1. Sea bream took natural food more readily than artificial food and fed more intensively in the warmer part of the year than in the colder part.
2. Natural food consumption considerably exceeded artificial food consumption. Variations in food consumption coincided with temperature variations. The analysis showed statistically significant dependence.
3. Length and weight increment was particularly intensive (A — 7.12 cm, 66.1 g; B — 7.45 cm, 64.7 g) in both groups at the beginning of the experiment (August, September, October). About the middle of the experiment fish growth showed decrease and reached very low values (A — 0.59 cm, 4.1 g; B — 0.92 cm, 6.4 g) in winter (January, February, March).
4. Weight-length relationship varied within narrow ranges. Weight mainly changed by length cube, that is sea bream showed isometric growth. Somewhat higher exponent values were recorded in fish fed on natural food.
5. Monthly conversion factor values were considerably lower in fish fed on artificial food (2.6—16.9) than in fish fed on natural food (5.1—32.0). For the thorough period of the experiment the conversion factor was: A — 4.3 and B — 8.0.
6. Condition factor was somewhat higher in fish fed on artificial food (1.41—1.67) than in fish fed on natural food (1.33—1.56).
7. Fish from both experimental groups showed high growth coefficient close to that of fish from the natural environment of the western Mediterranean. The data showed that fish fed on artificial food grew faster ($K = 0.285$) than fish fed on natural food ($K = 0.269$).

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O EKSPERIMENTALNOM HRANJENJU KOMARČE (*SPARUS AURATA* L.) U AKVARIJSKIM UVJETIMA

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KRATKI SADRŽAJ

Komparativno eksperimentalno hranjenje mlade komarče iz obalnih voda srednjeg Jadrana umjetnom i prirodnom hranom izvršeno je s ciljem da se pridonese poznavanju ishrane komarče u uvjetima kaptiviteta za potrebe njezina što racionalnijeg uzgoja.

Opažanja su bila izvršena u sistemu s otvorenom cirkulacijom morske vode.

Uvjeti sredine bili su sličnim onima u površinskom sloju mora u neposrednoj blizini Instituta.

Ribe su podijeljene u dvije skupine i hranjene umjetnom odnosno prirodnom hranom.

Upotrebljena umjetna hrana bila je sastavljena od ribljeg i pšeničnog brašna, pivskog kvasca, vitaminskog premiksa i kokošjeg jajeta (prvenstveno radi povezivanja svih komponenata hrane). Kao prirodna hrana služila je najčešće srdela, a u njenom pomanjkanju dagnja ili lignja.

Komarča je radije uzimala prirodnu nego umjetnu hranu, a intenzitet uzimanja hrane bio je veći u toplijem nego u hladnijem dijelu godine. Potrošnja prirodne hrane bila je znatno veća od potrošnje umjetne hrane. Kretanje potrošnje hrane pratilo je promjene temperature. Analiza je pokazala statistički signifikantnu zavisnost.

Dužinski i težinski prirast bio je početkom eksperimenta kod obiju skupina vrlo intenzivan. Sredinom eksperimenta je opadao, da bi u zimskim mjesecima bio vrlo malen.

Odnos između ukupne dužine i težine komarči kolebao je tijekom eksperimenta u razmjerno uskim granicama. Težina se uglavnom mijenjala s kubom dužine. Nešto više vrijednosti eksponenta zabilježene su kod primjeraka hranjenih prirodnom hranom.

Mjesečne vrijednosti stupnja konverzije bile su uvijek znatno niže kod riba hranjenih umjetnom nego prirodnom hranom.

Veće vrijednosti koeficijenta kondicije zabilježene su kod riba hranjenih umjetnom hranom.

Ribe iz obje skupine pokazuju visok koeficijent rasta, blizak onima u prirodnoj sredini zapadnog Mediterana.