Growth, food conversion and agonistic behaviour in common dentex (*Dentex dentex*) juveniles fed on pelleted moist and dry diets

Stefan Efthimiou [(1)], Pascal Divanach [(2)] and Harald Rosenthal [(1)]

[(1)] *Institut für Meereskunde an der Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany.*

[(2)] *Institute of Marine Biology of Crete, 71003 Iraklio, Crete, Greece.*

Accepted September 19, 1994.

Efthimiou S., P. Divanach, H. Rosenthal. *Aquat. Living Resour.*, 1994, **7**, 267-275.

Abstract

Juveniles of the common dentex (*Dentex dentex*) (2.4 g mean weight), were grown over a 6-week period, fed exclusively on a commercial sea bream diet or an isocaloric moist pellet diet, which was produced on site. Ambient temperature (24.4-26.2°C) and oxygen content (4.8-5.9 mg/L), as well as the relatively low stocking density (max. 2.62 kg/m^3) provided favourable rearing conditions. Survival (63.8 % vs 51.6 %), specific growth rates (6.1 % vs 4.5 %) and food conversion efficiency (115.8 % vs 76.3 %) were considerably elevated in the group fed on moist pellets. The growth performance parameters recorded are considered to be favourable for aquaculture requirements. Agonistic behaviour (particular biting of the tail) was found to be the main cause of the continuous mortality that occurred in both feed groups (78 % and 64.8 % of total mortality in the dry- and moist-pellet group, respectively). These biting attacks targeted the smallest individuals in a tank, whose mean individual weight made up 49-62 % (with dry pellet diet) and 28.9-46.6 % (with moist pellet diet) of the respective mean weights. The results indicate a strong relationship between nutrition, size variation and agonistic behaviour in the rearing of common dentex juveniles.

Keywords: *Dentex dentex*, Sparidae, feeding, survival, growth, food conversion, agonistic behaviour, aquaculture.

Croissance, taux de conversion alimentaire et comportement agressif chez des juvéniles du denté commun (Dentex dentex) *nourris au moyen de granulés humides et secs.*

Résumé

Des juvéniles du denté commun (*Dentex dentex*) (2,4 g de poids moyen) ont été élevés durant une période de 6 semaines et nourris exclusivement à base d'aliment commercial pour daurade ou bien à base de granulés humides isocaloriques qui ont été produits sur place. La température ambiante (24,4-26,2°C), la teneur en oxygène dissous (4,8-5,9 mg/l) ainsi que la densité relativement faible des poissons (max. 2,62 kg/m^3) se sont avérées des conditions d'élevage favorables. Le taux de survie (63,8 % vs 51,6 %), les taux de croissance spécifiques (6,1 %, vs 4,5 %) et le taux de conversion alimentaire (115,8 % vs 76,8 %) ont été considérablement élevés dans le groupe de poissons nourris de granulés humides. Les paramètres de croissance enregistrés sont considérés comme favorables pour l'aquaculture. Des comportements telles que des morsures de queue ont été les causes principales de mortalité observée dans les 2 groupes (78 et 65 % de la mortalité totale des groupes nourris à base de granulés secs et humides respectivement). Ces attaques de morsures ont porté sur les individus les plus petits dans un bac, dont le gain en poids moyen individuel a augmenté de 49-62 % (granulés secs) et 29-47 % (granulés secs). Les résultats indiquent une forte relation entre l'alimentation, la taille des poissons et le comportement agressif dans l'élevage de juvéniles de denté commun.

Mots-clés : *Dentex dentex,* Sparidae, alimentation, survie, croissance, taux de conversion alimentaire, comportement, aquaculture.

INTRODUCTION

The common dentex, *Dentex dentex* (L., 1758) is a highly valued table fish in the Mediterranean region and elsewhere in the tropics. Continuously increasing catches from 1984, 5404 to 8742 tonnes in 1990 (FAO, 1992) suggest a high, and not sufficiently satisfied market demand for this sparid fish.

Common dentex inhabit the Mediterranean Sea most commonly south of 40°C, rarely in the Black Sea, in the Atlantic from the Bay of Biscay to Cape Blanc and Madeira, but not around the British Isles (Bauchot and Hureau, 1986).

Recently, first studies on fecundity, egg and larval development have been based on preliminary rearing experiments (Glamuzina *et al.*, 1989; Franicevic, 1991; Kentouri *et al.*, 1992). Rearing experiments with juveniles (unpubl. data) have identified *D. dentex* as principally highly suitable for intensive aquaculture. The high fecundity of more than one million eggs/kg female exceeds that of already established aquaculture species like the gilthead bream (*Sparus aurata*) and the European sea bass (*Dicentrarchus labrax*). The common dentex, like many other Sparidae, seems to be a protandric hermaphrodite, but sex reversal is not likely to be obligatory (Bauchot and Hureau, 1986). The extended spawning period lasts from the end of March till July in the Mediterranean region (Lo Bianco, 1909; Bauchot and Hureau, 1986; Glamuzina *et al.*, 1989). The common dentex has been shown to be a partial spawner releasing pelagic eggs with the female releasing eggs during a 2 to 3 week period (Glamuzina *et al.*, 1989).

Raising of 3 g fry in 90 days from hatching has recently been reported by Bibiloni (1993), but survival was still relatively low (2 %). A total length of 270 mm was reported from 13 months old specimens fished in the Gulf of Neapel (Lo Bianco, 1909).

The rearing of common dentex, as recently carried through in laboratories and on a larger scale in several Mediterranean hatcheries, is usually associated with microbial infections and heavy cannibalism in larvae and juvenile fish, which has until now made commercial production impossible. Nearly all authors suggest nutritional deficiencies as the main cause for the reported problems and recommended specific nutritional investigations as the key to success in rearing of *Dentex dentex*.

Taking the currently available results from literature and our own rearing experience into account, it is assumed that commercially available sea-bream diets today do not sufficiently fullfil the nutritional requirements of common dentex. To evaluate the effects of diets on the rearing success of juveniles, the experimental approach of this study is based on a comparison of high-quality sea bream pellets with prepared moist pellets. The moist pellet diet was prepared to closely resemble the natural diet of strict carnivorous species. It was richly supplemented with vitamins and HUFAs, although as yet nothing is known about specific nutrient requirements. This pellet was thought to serve as a reference diet, allowing identification of the deficiencies in growth performance, food conversion and mortality associated with the use of commercial diets.

MATERIAL AND METHODS

Experimental set-up

In May/June 1993, larvae of *D. dentex* were reared in a semi-intensive mesocosm, a technique based on Japanese experience and further development by Divanach and Kentouri, 1983. Larvae close to metamorphosis (21 days after hatching, 10-12 mm TL) were transferred to circular tanks of 1.3 m^3 volume. Light intensity was adjusted to 200-1 800 lux by shadowing the tanks. The use of black-coloured, high tank walls (40 cm above water level) seems to have been necessary to reduce stress effects and to avoid the loss of fish by jumping out of tanks. The experimental tanks were supplied with fresh sea water at a theoretical exchange rate of 100 %/h, sufficient to provide good water quality throughout the experiment. 65 days after hatching, fry averaged 1.3 g (SD±0.36). They were distributed at random to 6 tanks in groups of 150 fish, resulting in a relatively low stocking density of 0.12 fish per litre. During a 12-day acclimation period, feeding was gradually changed from moist pellets to a commercial dry diet (Lansy 4, Artemia Systems, Ghent) in 3 tanks, whereas in another three tanks feeding was continued by using the initially fed moist pellets. Fish accepted this new food very fast, but appetite decreased after a few days. To provide the same initial stocking density in all experimental tanks at the beginning of the test-trial, mortality losses were compensated by restocking (n=150). The test-trial lasted for a six-week-period during which 3 parallel tanks were fed solely on either the dry or the moist pellet diet.

Feed and feeding regime

The feeding techniques in this comparative study differed considerably as they referred to the specific properties of each test diet. Dry pellets were administered on conveyer-belt-type automatic-feeders, whereas the moist pellet was fed ad libitum by hand five times a day at two-hour intervals. The daily feeding period lasted from 7.30 h-18.00 h for both diets. Feed loss was determined in the dry pellet group during a 3-day period, by collecting pellets remaining on the feeder and pellets, which had fallen to the bottom of the tank. Of the dry weight of these two fractions a total mean loss of 25 % (20.3-29.6 %) was determined in the dry pellet group. The feed loss related to the hand-feeding of moist pellets was not determined separately, because only dissolved matter and negligible amounts of particles remained in the tank after feeding.

The moist pellet was prepared to incorporate partly natural diets of the common dentex. As no reliable information on the complete natural food composition was available, various fish species (*Trachurus mediterraneus, Merluccius merluccius, Engraulis encrasicolus, Boops boops, Spicara maena*) from the local market were chosen as ingredient source. To make grinding easier and to incorporate skeletal parts into the moist pellet, bigger fish (>50-100 g) were filleted and smaller fish (<50 g) were taken as a whole fish, with only head and fins removed. The fish were cut in small pieces and mixed with the same commercial dry pellet used in the parallel test group in a relation of 75% fish to 25% pellet. To prevent vitamin and essentially fatty acid deficiencies, the moist pellet was supplemented with Vitamin C (2 g/kg), a vitamin mix, Aquace (2 g/kg), and HUFA oil, Aquatak (15 ml/kg), (Peter Hand Aquahealth Medicines, Stanmore, UK). This premix was ground until a homogeneous paste was obtained. Storage lasted not longer than 2 weeks at –10°C in the freezer and one day in the refrigerator. Dry pellets were stored at a constant temperature (5°C) and fed as instructed by the producer. Two pellet size classes (0.8-1.2 mm, 1.2-2.0 mm) were subsequently offered relating to fish growth. The moist pellet was fed in considerably bigger pieces ranging from 3.0-10 mm owing to its higher water content. To make the nutritional value of the diets comparable, ingredients were mixed in ratios to attain isocaloric values (see *table* 1).

The energy content of the test diets was determined by bomb calorimetry using a Phillipson oxygen microbomb calorimeter (2% accuracy).

Table 1. – Some characteristics of the basic composition of the experimental diets and their isocaloric value. Dry pellet: Lansy 4 by Artemia Systems, Ghent).

	Dry pellet	Moist pellet
Moisture (%)	8-10	50-52
Energy content (kJ/g dry matter)	23.76	23.35
Composition	100% pellet	75% fish 25% pellet
Size range (mm)	0.8-1.2 1.2-2.0	3-10

Measurements

Weight-length measurements were conducted weekly by sampling of 15 fish per tank (10-17% of each tank population). Live fish were anaesthetized with Ethyleneglycolmonophenyl-ether ($C_8H_{10}O_2$) 0.2-0.4 ml per litre and measured under a binocular microscope to 0.1 mm accuracy. For weight measurements, fish were initially placed on filter paper to remove external water, and thereafter immersed in a water filled, tarred vessel on an analytical balance (Sartorius, 0.001 g). During handling, fish were kept in a bucket at low densities (1 individual per litre) and oxygenated water was supplied (130-150% saturation), thereby supporting quick recovery from anaesthesia and largely reducing stress symptoms. Fish recovered after 10-30 seconds from the anaesthetic and were then immediately transferred back to their rearing tanks. Directly after the return of fish to tanks no cannibalistic attacks against these fish by tank-mates could be observed.

Dead fish were removed, counted and examined for injuries daily after the morning feed (7:30 a.m.). Dying and dead fish were almost always attacked by their tank-mates and therefore many of them lost their tail. It was assumed that these fish were lost because of agonistic behaviour of conspecifics. Due to the missing tail, total length could not be used to assess the size class of these fish and the head length was determined instead. Previous measurements established a strong correlation between head length and body wet weight with this relationship being used in this study to back-calculate the size of moribund and dead fish (*fig.* 1).

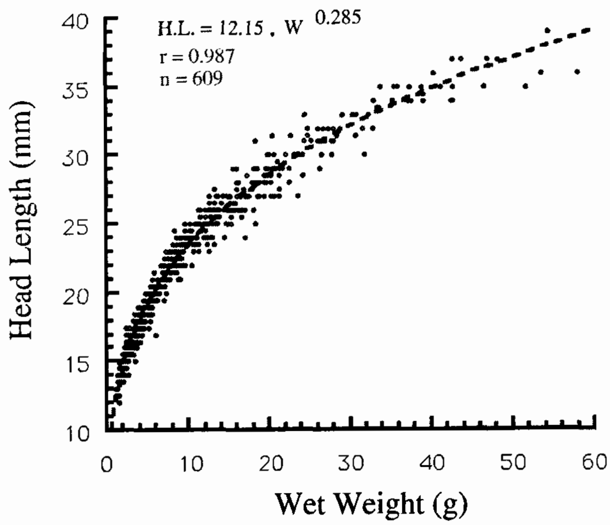

Figure 1. – Exponential relation between wet weight and head length in juvenile *Dentex dentex*. H.L.: Head length, W: wet weight, *r*: correlation coefficient, *n*: number of fishes.

Agonistic behaviour has been defined for the purpose of this study as repeated attack (particularly biting) by conspecifics. This agonistic behaviour can be classified as a filial (when coming from parents) or sibling- (different parents) intracohort relationship, similar to the classification of cannibalism by Smith and Reay (1991).

Calculation of growth and food conversion factors

For comparison of growth and food conversion between the two test diets of the experiment the following factors were determined:

a) specific growth rate (SGR) = (ln final weight (g) – ln initial weight (g)/time (days) × 100;

b) coefficient of variation (%) = standard deviation/arithmetic mean × 100;

c) feeding rate (%) = daily amount of feed dry weight (g)/biomass wet weight (g);

d) food conversion rate (FC) = amount of feed dry weight (g)/biomass wet weight increase (g).

Food conversion efficiency (%) = biomass wet weight increase/amount of feed dry weight (g).

Water quality control

Water quality data were determined daily (3:00 p.m), separately for every culture unit. Oxygen concentration was measured with an oxygen-meter (Model 57, YSI) and temperature and pH with a combined pH- temperature sensor (C-925, Consort). Salinity was determined daily in one tank using only a hand refractometer from Atago. Values for temperature (range 24.4-26.2°C), oxygen (range 4.8-5.9 mg/l), pH (range 7.7-7.8) and salinity (41-42 ppt) were relatively constant. Total ammonia and nitrite levels were not monitored because pre-trials under similar rearing conditions showed no elevated levels under the given fish load.

At the beginning of the experiment and after 3 weeks a prophylactic antibiotic treatment was conducted (in a water-bath) over three subsequent days (Furaltadon, 100 ppm for 60 min). A strong production of mucus was observed in tanks fed with the moist pellets, indicating an ectoparasitic infection. This was treated successfully by a double formalin bath (100 ppm for 30 min), applied at one-week intervals.

Statistical analysis

Growth curves were compared by regression analysis of logarithmic (log) transformed mean values ($n=45$). Logarithmic transformation of mean weight values plotted against time gave a strong linear relationship, and the regression coefficients (slopes) were compared by analysis of variances after Sokal and Rohlf (1981). Regression lines of triplicates were not different and therefore their pooled data were used in the final analysis. To compare the coefficient of variation and the relative size of "cannalibalized" fish the U-test (Mann and Whiney) for equal sample sizes was applied.

RESULTS

Growth

Juvenile *Dentex dentex* fed on the moist pellets showed a significantly better growth during the six-week feeding trial than fish fed on dry pellets (*fig.* 2). Mean individual weight was attained in fish fed dry pellets 16.12 (standard error ± 1.58 g) (6-fold their initial weight), whereas fish fed on moist pellets attained more than 12 times their initial weight and reached a final mean weight of 31.3 (SE ± 1.45 g). Growth data are summarized in *table* 3.

Table 2. – Characteristics of the linear regression analysis of logarithmic transformed growth curves presented in Figure 2. Form of the equation: $\text{Log}\,W = a + bT$. W = Wet weight; $a = y$ intercept, b = slope; s.e. (b) = standard error of b; T = time, r = correlation coefficient.

	a	*b*	s.e. (b)	*r*
Dry pellet	0.418	0.138	0.055	0.992
Moist pellet	0.409	0.192	0.011	0.984

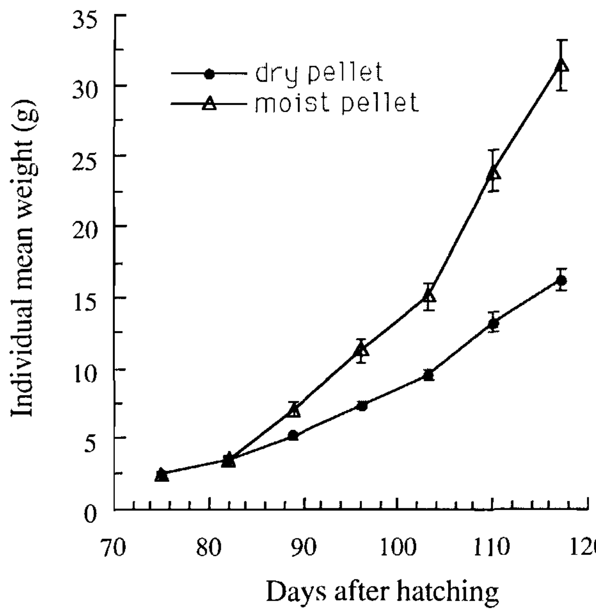

Figure 2. – Growth (wet weight basis) of juvenile *Dentex dentex*, fed moist or dry pellets. Mean values and standard error from 3 replicates ($n=45$) are shown. The trial lasted 6 weeks (day 75-117 after hatching).

The logarithmic transformation of the growth curves leads to linear regression lines with a high coefficient of correlation (*table* 2). A comparison of the slopes (b) of the two regression lines proved the significant higher growth rate to be in the moist pellet group ($p<0.01$). The corresponding specific growth rates (SGR, *fig.* 3) varied with time between 2.85%

Table 3. – *Dentex dentex* rearing trials. Mean weight (g), standard deviation (SD) and coefficient of variation (CV) at the beginning of every week. Feeding rate, food conversion factor (FC) and the specific growth rate (SGR) for a feeding experiment, lasting 6 weeks and comparing a commercial dry pellet (Lansy 4, artemia systems, Ghent) and a moist pellet produced on site. All determinations are based on a sample size of $n=45$. B.w. = body wet weight.

	Dry pellet					Moist pellet				
	Mean weight	C.V.	Feeding. rate	Food-Conv.	SGR	Initial weight	C.V.	Feeding. rate	Food-Conv.	SGR
week	x (g)± SD	(%)	(% B.w.)		(% B.w./day)	x (g)± SD	(%)	(% B.w.)		(% Bw/day)
1	2.43±0.64	25.2	2.96	0.59	5.62	2.46±1.08	43.7	6.85	1.44	4.80
2	3.59±1.39	36.9	4.59	1.44	5.11	3.45±1.66	47.7	5.78	0.59	10.24
3	5.17±1.32	15.7	4.39	0.98	5.19	7.06±3.74	53.0	4.72	0.76	6.56
4	7.39±2.15	29.2	3.76	1.04	3.75	11.17±5.83	52.3	4.26	1.02	4.64
5	9.60±2.81	29.3	3.47	0.79	4.55	15.46±6.44	41.5	4.50	0.76	6.25
6	13.19±4.66	35.3	4.31	1.70	2.85	23.9±9.64	40.4	4.57	1.34	3.84
7	16.16±5.32	33.1				31.3±12.97	42.1			

(week 6) and 5.62% (week 1) in the dry pellet group whereas fish fed on moist pellets showed SGR values between 3.84% (week 6) and 10.24% (week 2). More common were SGRs between 5 and 6% in the dry pellet and 6 and 7% in the moist pellet groups. Parallel tanks, belonging to the same feeding group, expressed only small deviations from the means (not shown in *fig.* 3).

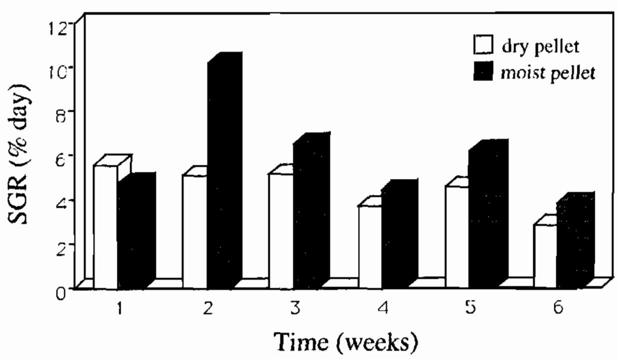

Figure 3. – Specific growth rates (SGR expressed as % body weight per day) of juvenile *Dentex dentex* fed on dry or moist pellets. Mean weight ranged 2.43 g (week 1) and 16.2 g (week 6), dry pellet group and between 2.46 g and 31.3 g in the moist pellet group. Water temperature: 25±0.5°C, salinity: 40 °/₀₀, max. stocking density: 2.62 kg/m^3.

The size variability during the experiment is expressed by the coefficient of variation (C.V.), (*fig.* 4). Fish fed on moist pellets showed a significant ($p<0.05$) higher size variation during the entire experimental period compared to fish fed the dry pellet diet. Between week 4 and 6 the coefficient of variation was lower (40%) than during the previous weeks in the moist pellet group (50%), while the relative size variability in the dry pellet group almost remained at the same level (C.V. = 30-35%). Although all tanks were stocked randomly and mean weights corresponded very well (*table* 3), the initial size distribution was already different between the two diets, resulting in a higher standard deviation and C.V. value in fish fed on moist pellets.

Mortality and agonistic behaviour

All three parallel tanks fed on dry pellets showed lower survival rates with time than fish fed on moist pellets (*fig.* 5 and 6). It is assumed that the mean total mortality of 48.4% (dry pellet) and 36.3% (moist pellet) observed over the entire experimental period (42 days) was mainly due to biting attacks of tank mates (*fig.* 6) in both test groups. Mortality directly related to agonistic behaviour rose also in the dry pellet fish group reaching 78.5% compared to fish fed the moist pellets. In this group bitings were found to be the reason for death in only 64.8% of the dead fish (*fig.* 6). Biting attacks were most commonly directed against the smallest individuals inthe tanks, as shown in *figure* 7.

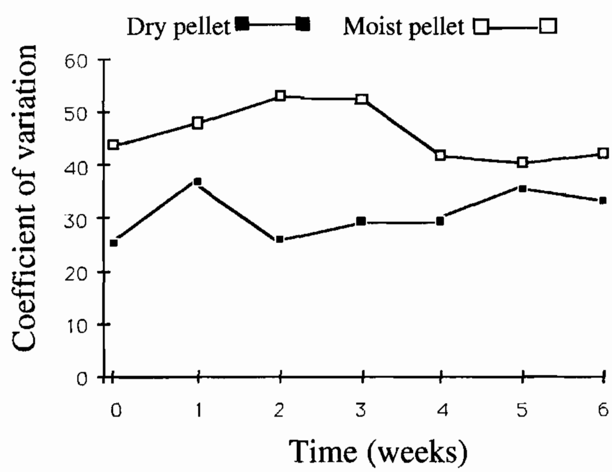

Figure 4. – Changes in the coefficient of variation (%) (SD/arithmetic mean × 100) for juvenile *Dentex dentex* fed isocaloric dry or moist pellets. Calculations are based on weekly samples of 45 fish from each group (10-15% of total number).

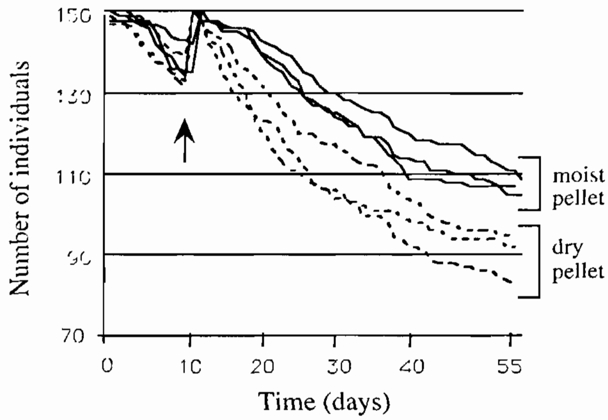

Figure 5. – Survival of juvenile *Dentex dentex* fed two different diets, a moist and a dry pellet. Each line represents a single fish tank. Day 1-12 acclimation, day 13-55 experimental period. The arrow indicates the restocking ($n = 150$) at day 12.

The wet weights of dead fish (which had died from frequent attacks) made up only 25-60 % of the respective mean weight of the surviving fish. Although the absolute weight of fish died through bitings was quite similar in both groups, the relative size was significantly lower in the moist pellet group (34.5 % vs 53.8 %) (*fig.* 7). Furthermore, the relative size of fish which had died through bitings, in the moist pellet group showed a decreasing tendency: 46 % in weeks 1 and 2; 30-40 % in weeks 3 to 6. A slight increase of this size was observed in the dry pellet group (*fig.* 7).

Agonistic behaviour was observed to occur in larger specimens by hunting and biting smaller individuals. The attack was almost always directed towards the tail of the subordinate fish. Bitten fish, with a bloody tail and staggering swimming movement, were attacked more frequently. The intensity of agonistic behaviour decreased during the experiment. No true cannibalism (ingestion of a complete tank mate) occurred during the obervational period.

Food conversion

Daily feeding rates in the dry-pellet fish were about 1-3 % lower than feeding rates observed in moist-pellet fish. This difference was even greater during the first two weeks, when feeding rates in the moist-pellet fish were high (6.85 %, 5.78 %), and at the same time, low in the dry-pellet fish (week 1 = 2.96 %). During the last 4 weeks of the experiment fish fed ad libitum with moist-pellets showed a very constant feeding rate of 4.26-4.78 % of their biomass per day. In this period, feeding rates of the dry pellet fish also varied little (3.47-4.39 %), but were still lower than in the moist-pellet fish.

Food conversion factors varied between 0.59 and 1.44 in fish fed the moist pellets, while these values ranged between 0.59 and 1.70 in the dry-pellet fish. The best food conversion factors found in both diets, with FC = 0.59, corresponded with the highest specific

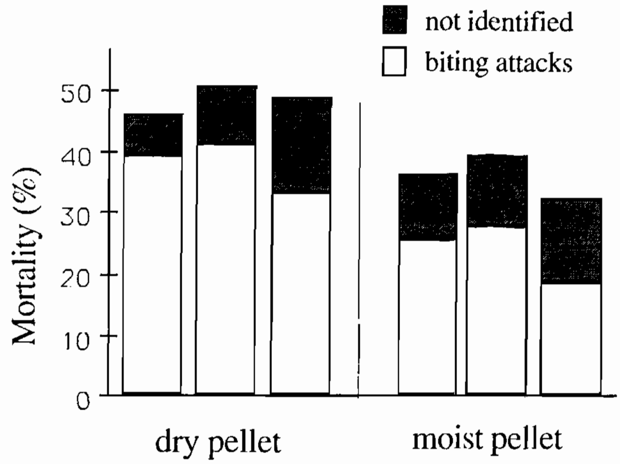

Figure 6. – Total mortality rates, expressed as % of the initial number ($n = 150$ per replicate) of juvenile *Dentex dentex* for the experimental period (6 weeks), the part of mortality which was related to biting attacks of conspecifics (white columns) and the remaining unexplained mortality (black columns) is given for both test diets and each replicate tank.

growth rates of 5.62 % in week 1 (dry pellet) and 10.24 % week 2 (moist pellet).

DISCUSSION

The specific growth rates (SGR) determined in both test diets over the whole experimental period showed high mean values of approximately 5 % of body weight per day. These compare favourably with the high values reported for other warm-water species of a similar size range and reared at almost the same temperature. Channel catfish (*Ictalurus punctatus*) increased from 3 to 12.5 g at 28°C in 4 weeks, resulting in a SGR of 5 % (Stickney *et al.*, 1972). Hogendoorn *et al.* (1983) found SGRs for African catfish (*Clarias lazera*) fingerlings (0.3-40 g) to be 6-7 % of body weight per day at 25°C in an intensive rearing experiment, although at a higher feeding level. Other sparids, used in aquaculture in the Mediterranean area, such as the gilthead sea bream (*Sparus aurata*) are reported to show lower growth rates. Kissil and Koven (1987) tested 5 diets and found SGRs between 2.1 and 3.34 for sea bream fry (1.3-5.3 g) at high feeding rates (6 %) and temperatures (25-28°C). In a study on food attractants, fingerlings of sea bream (10 g fish) reared at 25.6°C showed specific growth rates of only 1 % of body weight/day (Tandler *et al.*, 1982). Divanach *et al.* (1992) compared the growth performance of 2 established aquaculture species, the European sea bass (*Dicentrarchus labrax*) and the gilthead sea bream with 4 Mediterranean sparids (*Pagrus pagrus: Puntazzo puntazzo: Diplodus sargus sargus, Diplodus anularis*). They found specific growth rates of 2.54 % (juvenile sea bream) and 2.27 % (juvenile sea bass), whereas the other species showed similar or lower growth rates. The authors note that these growth rates were high compared with literature

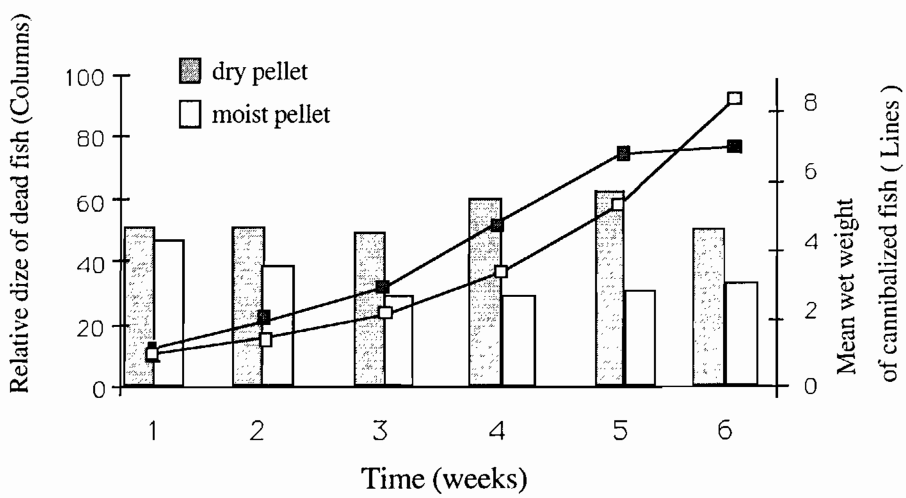

Figure 7. – Change in size of dead individuals in juvenile *Dentex dentex* (lost due to biting attacks) during a 6-week rearing trial. Fish were reared on two different diets. Columns indicate the relative size of fish lost by biting when compared to the average size (weight) of the population in the tanks at a time when the mortality was observed. Lines indicate mean wet weight of fish by biting. Total number of fish per tank fluctuated due to varying mortality between 5 and 30 specimens.

values. These data comparisons indicate the high growth potential of common dentex juveniles.

Specific growth rate is size-dependent and decreases with increasing individual weight of fish (Ricker, 1979; Jobling, 1983). This fact could largely explain the SGRs observed over the last 3 weeks, and especially during the last week of the experiment, when the lowest SGRs of both test groups were recorded. Furthermore, accumulated handling stress may also be responsible for these reduced growth rates.

In line with the high growth potential, highly efficient food conversion rates between 0.59 and 1.44 (moist pellet) and 0.59 and 1.70 (dry pellet) were found in this study. Optimal food conversion rates were similar to the conversion rates found by Hogendoorn (1983) for African catfish fingerlings (FC = 0.58). These exceptionally low food conversion rates coincide with the highest specific growth rates and indicate optimal rearing conditions. However, the observed mean conversion efficiency was lower with a mean feed conversion rate (FC) of about 1. In comparison with other warm-water aquaculture species, *e.g.* the European eel (*Anguilla anguilla*) which reached an optimal value range of FC 1.3-1.8 (Koops, 1991; Seymour, 1989), and the gilthead sea bream (*Sparus aurata*) which achieved optimal values of FC = 1.62 (Kissil and Koven, 1987), the observed food conversion efficiency for both test diets in this study was within the range of optimal values for established species.

When comparing food conversion factors of the dry and moist pellet diets, one has to consider that FC-values for the dry-pellet group were calculated by taking into account a 25% feed loss. On the other hand, the moist-pellet values were actual gross conversion rates. Therefore, the moist pellets showed a mean gross conversion efficiency approximately 30-35% higher than that of the dry pellets. The high variation in food conversion efficiency, which was determined for both diets throughout the experiment is most probably due to variations in appetite, growth, and feed loss.

The feeding rates recorded are similar to values reported for other warm-water aquaculture species. For example, Hogendoorn (1983) found daily feeding levels of 6.5%, 4.7% and 3.4% of body weight for 1-, 5- and 25 g fish, respectively, for the African catfish (*Clarias lazera*) at a temperature of 25°C. This corresponds well with the decrease of feeding levels found in fish fed by moist-pellets over the experimental period (*i.e.* 6.85% week 1, mean weight 3.0 g and 4.57% week 6, mean weight 28.6 g). Feeding levels in the dry-pellet group were relatively constant and slightly lower than those in the moist-pellet group. Dry pellet values have to be treated with care, as feed loss could not be determined continuously. Thus, any variations in feed loss that occurred over the experiment will not be manifested in the feeding rates.

The relatively high mortality rates found in both test groups were mainly associated with agonistic behaviour, which is common among the post-larvae and juveniles of many fish species (Brownell, 1989; Knights, 1987; Smith and Reay, 1991; Hecht and Pienaar, 1991). Size difference is considered to be an important factor in determining dominance (Knights, 1987; Parazo *et al.*, 1991; Peters, 1980). Results of the present study confirm this trend in common dentex, as smaller fish most commonly died as a result of biting attacks. The test diets appear to have had different effects on aggression and subsequent mortality. Though the relative size variability was considerably higher in those fish fed on moist pellets (as indicated by the higher coefficient of variation), the percentage of fish that died from biting attacks was lower. Furthermore, the relative and absolute size of attacked fish was here lower than in those groups fed on dry pellets. This higher level of social stress that obviously occurred in fish fed dry pellets could be one possible reason for the lower feed intake and reduced growth rates. Pickering (1993) pointed out that social stress, on a sub-lethal level, can cause growth retardation as a result of reduced feeding. Knight (1987) found in young eels that subordinate animals expressed a higher activity level, reduced food consumption, lower growth rates and a higher mortality.

The initial differences in size variability found within the two test groups may have been caused by an accidental selective stocking. It is not clear whether the higher size variation in the moist pellet group, which can be observed throughout the whole experiment, originates from this initial difference between the two test diets or is related to the subsequent faster growth in the moist pellet fish.

Grading will probably reduce this agonistic behaviour, and mortality directly related to biting attacks is expected to decrease, if undersized fish are separated from well-growing fish. Agonistic behaviour seems also to be strongly related to nutrition and can cause growth retardation even when no mortality occurs (Ruzzante, 1994).

Observed differences in growth between the two different dietary groups however could have resulted from factors such as: (a) a higher level of attraction to moist pellets (due to structure, particle size, smell etc.); (b) a preference for the feeding mode used for the moist pellet diet; (c) a better digestibility of a moist pellet diet, which is of lower energetic value per unit volume (Jobling, 1986); (d) the difference in the approximate composition and the additives put in the moist pellets, which may have fulfilled the species-specific requirements of *Dentex dentex* better than those of the dry pellets, which are known to influence growth rates.

Therefore, the exact interactions of the above relationships between behaviour, nutrition and metabolism of the common dentex will have to be studied more intensively in the future.

Although the rearing trials described here were not designed to identify specific nutritional requirements for the common dentex, a strong relationship between nutrition and agonistic behaviour was indicated. In addition, reliable data on growth and food conversion rates for this potential culture species was provided for the first time. Commercial sea-bream diets would have to be modified before they could become acceptable in dentex culture. The use of a moist pellet as a basis in further nutritional studies of dentex could provide a more reliable basic diet than dry feeds.

Note: This paper is part of the PhD-thesis of the first author.

Acknowledgements

The authors wish to acknowledge the assistance of the Institute of Marine Biology of Crete to carry out the experiments in their facilities. In particular we are indebted to Prof. M. Kentouri for providing the infrastructure. Further help during rearing and handling of fish was obtained from Mr. G. Koumoundouros.

REFERENCES

Bauchot M. L., J. C. Hureau, 1986. Sparidae. *In*: Whitehead P. J. P., M. L. Bauchot, J. C. Hureau, J. Nielsen, E. Tortonese, ed., Fishes of the North-eastern Atlantic, and the Mediterranean 2, UNESCO, Paris, 883-907.

Bibiloni G., A. Cladera, M. A. Gomila, S. Massutí, I. Zaratiegui, 1993. Contribution to the growing of *Dentex dentex*. *In*: Carillo M., L. Dahle, J. Morales, P. Sorgeloos, N. Svennevig, J. Wyban, eds. From Discovery to Commercialization. Abstracts of contributions presented at the international Conference World Aquaculture'93, Toremolinos, Spain, May 26-28. EAS Spec. Publ., 19, Oostende, Belgium.

Brownell C. L., 1989. Factors affecting agonistic behaviour in reared juvenile dolphin (*Coryphaena hippurus*). *In*: The early life history of fish. The third ICES Symposium, Bergen, 3-5 October 1988, eds., Blaxter J. H. S., J. C. Gamble, H. V. Westernhagen, 485.

Divanach P., M. Kentouri, 1983. The influence of initial trophic conditions on oil globule resorption, growth and survival of gilt head sea bream, *Sparus auratus*, larvae in extensive breeding. *Aquaculture*, **35**, 43-55.

Divanach P., M. Kentouri, G. Charalambakis, F. Pouget, A. Sterioti, 1993. *In*: Production, Environment and Quality. Barnabe G. and P. Kestemont, eds. European Aquaculture Society, *Spec. Publ.*, **18**, 285-297.

FAO, 1992. Yearbook of fishery statistics, **70**, Catches and landings.

Franicevic V., 1991. *EAS Spec. Publ.*, **14**, 106-107.

Glamuzina B., J. Jug-Dujacovic, I. Katavic, 1989. Preliminary studies on reproduction and larval rearing of common dentex, *Dentex dentex* (Linnaeus, 1758). *Aquaculture*, **77**, 75-84.

Hecht T., A. G. Pienaar, 1991. Cannibalism: The hidden mortality factor in larviculture. Larvi'91-Fish and Crustacean Larviculture Symposium (Lavens, Sorgeloos, Jaspers, Ollevier, eds), *EAS Spec. Publ.*, **15**, Gent, Belgium, 277.

Hogendoorn H., J. A. J. Jansen, W. J. Koops, M. A. M. Machiels, P. H. van Ewijk, P. van Hees, 1983. Growth and production of the African catfish, *Clarias lazera* (C. & V.) 2. Effects of body weight, temperature and feeding level in intensive tank culture, *Aquaculture*, **34**, 265-285.

Jobling M., 1983. Growth studies with fish - overcoming the problems of size variation. *J. Fish Biol.*, **22**, 153-157.

Jobling M., 1986. Gastrointestinal Overload - A Problem with formulated Feeds. *Aquaculture*, **51**, 257-263.

Kissil G. W., W. M. Koven, 1987. Comparison of test diets for the gilthead seabream (*Sparus aurata*). Bamidgeh, **39**, 84-91.

Kentouri M., G. Koumoundouros, P. Divanach, A. Sterioti, 1992. Développement embryonnaire du Pagre, *Pagrus pagrus* et du Denté, *Dentex dentex* en Crète. *Rapp. Commun. Int. Mer Médit.* **33**, 384.

Koops H., 1991. Zur Probematik von Kreislaufanalagen in der Fischzucht. Schriftenreihe des Bundesministers für Ernahrung, Landwirtschaft und Forsten, Heft 402.

Lo Bianco S., 1909. Notizie biologiche riguardanti specialmente il periodo di maturita sessuale degli animali del Golfo di Napoli. *Mitt. Zool. Stat. Napel*, **19**, 513 p.

Knights B., 1987. Agonistic behaviour and growth in the European eel, *Anguilla anguilla* L., in relation to warm-water aquaculture. *J. Fish Biol.*, **31**, 265-276.

Parazo M. M., E. M. Avila, Reyes, 1991. Size and weight dependent cannibalism in hatchery-bred sea bass (*Lates calcarifer* Bloch). *J. Appl. Ichthyol.*, **7**, 1-7.

Peters G., H. Delventhal, H. Klinger, 1980. Physiological and morphological effects of social stress in the eel (*Anguilla anguilla* L.). *Arch. Fisch Wiss.*, **30**, 157-180.

Pickering A. D., 1993. Husbandry and stress. *In*: Recent Advances in Aquaculture 4, Muir J. F., R. J. Roberts, ed., Blackwell Scientific Publications, 155-169.

Ricker W. E., 1979. Growth rates and models. *In*: Fish Physiology. W. S. Hoar, D. J. Randall, J. R. Brett, eds., vol. 3, 678-743. New York & London, Academic Press.

Ruzzante D. E., 1994. Domestication effects on aggressive and schooling behavior in fish. *Aquaculture*, **120**, 1-24.

Sokal R. S., F. J. Rohlf, 1981. Biometry. The principles and practise of statistics in biological research. Freeman and Company, New York, 859 p.

Seymour E. A., 1989. Devising optimum feeding regimes and temperatures for the warmwater culture of eel, *Anguilla anguilla* L. *Aquac. Fish. Manage.*, **20**, 129-142.

Smith C., P. Reay, 1991. Cannibalism in teleost fish. *Rev. Fish Biol. Fish.*, **1**, 41-64.

Stickney R. R., T. Murai, G. O. Gibbons, 1972. Rearing channel catfish fingerlings under intensive culture conditions. *Progress Fish Cult.*, **34**, 100-102.

Tandler A., B. A. Berg, G. W. Kissil, A. M. McKie, 1982. Effect of food attractants on appetite and growth rate of gilthead sea bream, *Sparus auratus* L. *J. Fish Biol.*, **20**, 673-681.