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Cultivation of the Mediterranean amberjack, *Seriola dumerili* (Risso, 1810), in submerged cages in the Western Mediterranean Sea

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Abstract

The growth rate, survival and food conversion ratio (FCR) of the Mediterranean amberjack (*Seriola dumerili*, Risso, 1810) was ascertained in cultivation using submerged net cages in the Gulf of Castellammare (NW Sicily), from September to December 1994. Two net cages (volume = 75 m^3) were placed at a depth of 10 m in a sheltered area 1000 m off the coast. Juveniles (mean total length = 141.4 ± 34.2 mm; mean total wet weight = 48 ± 28.1 g) were caught in the gulf under floating wreckage with a purse seine and transplanted to the cages ($n = 800$ per cage) in August. Fish in one cage, group A, were fed with fish scraps whilst fish in group B were fed with pellets. The total length and body wet weight were recorded each month and compared with the wild population of the gulf. Negligible mortality occurred due to capture and transportation to the cages and no diseases were found during the rearing period. Group A reached a final size of 438.1 ± 25.3 mm and 1149 ± 172.2 g, while group B reached 347 ± 25.6 mm and 576 ± 139 g. At this time the wild population was 404.13 ± 17 mm and 777 ± 89.4 g. Food conversion ratios of 1.22 for group A and 3.51 for group B were in the low range compared with other research on *S. dumerili* in the Mediterranean. *S. dumerili* seemed to find fish scraps more appetising than pellets. The low level of investment required, limited breeding period and compatibility with small-scale fishing make submerged net cages a promising system of cultivation for the conversion of coastal fishing. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: *Seriola dumerili*; Cage aquaculture; Open-sea; Feeding; Mediterranean Sea

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1. Introduction

The Mediterranean amberjack, *Seriola dumerili* (Risso, 1810), is a carnivorous pelagic fish (Carangidae) that is widespread along the Mediterranean coast (Fisher et al., 1987). This species lives at depths of 20–70 m, although it has also been caught at depths down to 360 m (Fisher et al., 1981; Fisher et al., 1987). The young are gregarious by nature and often associated with flotsam, together with *Naucrates ductor* (pilot fish) and *Coryphaena hippurus* (common dolphinfish). *Seriola dumerili* is an opportunistic species, with its diet varying as a function of its size (Mazzola et al., 1993; Matallanas et al., 1995; Pipitone and Andaloro, 1995). It represents an important resource for the southern Mediterranean countries (Andaloro et al., 1992).

In recent years, Mediterranean aquaculture has attempted to select new species of marine fish in order to diversify its production (Cahiers Options Méditerranéennes, 1995). The potential success of a species is based on market analysis, growth performance and on the availability of juveniles. *S. dumerili* is certainly a favourable species for Mediterranean aquaculture to develop. Amberjack are highly adaptable to culture in concrete tanks (Lazzari and Barbera, 1989; Garcia-Gomez, 1993; Greco et al., 1993) and in net cages (Boix et al., 1993; Mazzola et al., 1996), with high growth and survival rates (Porrello et al., 1993; Mazzola et al., 1996).

Research in the Mediterranean area has encountered great difficulty in obtaining spawning in captivity (Lazzari and Barbera, 1989; Manganaro et al., 1993; Lazzari and Di Bitetto, 1994; Marino et al., 1995a,b), despite the success obtained with the Japanese *Seriola quinqueradiata* (Masuma et al., 1990; Tachihara et al., 1993). The provision of 0 + juveniles represents a limit in the development of the cultivation of *S. dumerili* (Greco et al., 1991; Caridi et al., 1992; Mazzola et al., 1996). One solution to this problem could be the provision of juveniles in their natural habitat, although overfishing has caused a reduction in this resource (Mazzola et al., 1993).

Little information is available regarding the biology of the Mediterranean amberjack in cultivation (Giovanardi et al., 1984; Navarro et al., 1987; Porrello et al., 1993), its capture, transport (Greco et al., 1991) and dietary preferences (Garcia-Gomez, 1993).

This paper presents the results of the cultivation of Mediterranean amberjack in submerged cages using simple installation techniques of low technology and cost. Research was carried out to test the growth rate, survival and feeding parameters in captivity of two groups of fish fed two different diets. Their growth rates were compared with that of the wild population taken from the same area.

2. Materials and methods

Feeding trials were carried out between July 1994 and December 1994 in the Gulf of Castellammare (NW Sicily; 38°02′31″N; 12°55′28″E) in a sheltered area 1000 m off the coast. Collection of the juvenile fish and management of the cultivation activities were carried out by a co-operative of local fishermen.

Two cylindrical net cages of 75 m^3 (ϕ 4.5 m, h 5 m, and 12-mm mesh size) were moored onto artificial reefs, 18 m deep, and submerged 10 m below the water surface. Feeding was carried out by means of a mesh cone from the cage to the surface.

Fishermen caught the juveniles during the summer of 1994 from below fish aggregating devices (FAD). These FADs (artificial wreckage made of twisted cane mats) were

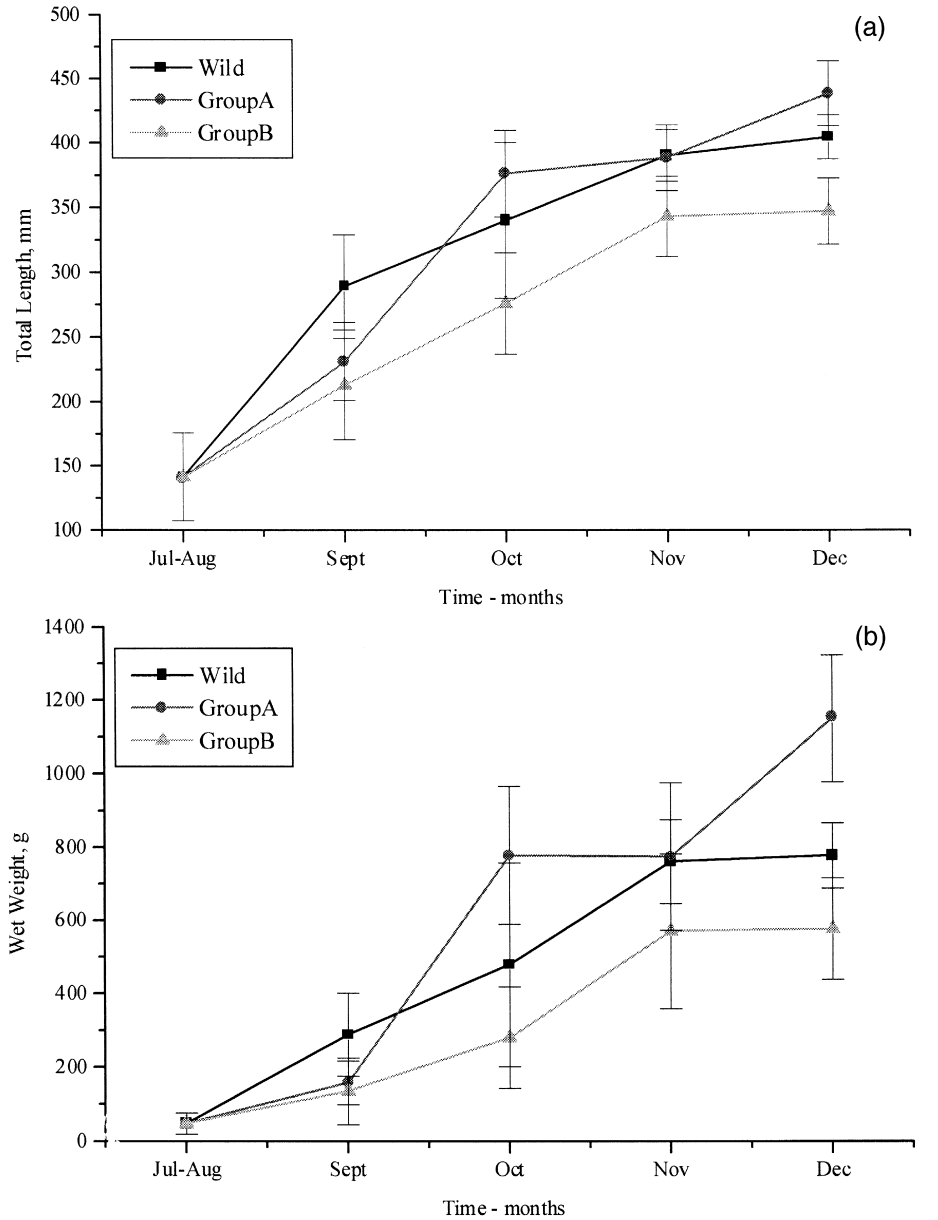

Fig. 1. Monthly trends of total length (a) and wet weight (b) of *Seriola dumerili* in cage culture and the wild.

moored to the sea bottom along a bathymetric gradient (5–120 m). The juveniles were caught with a small purse seine (150 m × 40 m and 20-mm mesh) and the total length (TL) and wet weight (T_{WW}) of sampled specimens recorded immediately. The fish were placed in PVC tanks (volume: 0.3 m^3) on the fishing boat, which was equipped with an open forced seawater system for transplanting to the cages (within 4 h). Amberjack specimens were placed into the cages ($n = 800$ per cage) at an initial density of 10 specimens m^{-3}.

During the rearing period (September–December), monthly samples of *Seriola dumerili* were taken ($n = 50$ per cage), TL and T_{WW} were measured and the fish then replaced inside the cages. At the same time, samples of wild *S. dumerili* were caught by the same group of fishermen in the Gulf of Castellammare and treated as above.

The first group of fish (A) to be placed in cultivation was fed with fish scraps obtained from Sicilian fisheries, while the second group (B) was fed with pellets (Trouvit Marine; Hendrix). The two groups were fed twice a day (at 7 am and 7 pm) and the total amount of food administered was determined according to the classic methods used in Mediterranean aquaculture (Lazzari and Barbera, 1989).

Growth performance was analysed by calculating the daily specific growth rate (Winberg, 1971) in somatic wet weight (C_w) and in length (C_l) ($C_{w/l} = [(\ln X_2 - \ln X_1)/\Delta t]$ where X represented length (TL) or weight (W). The relationship between the total length and somatic wet weight was calculated using a simple allometric equation ($W = aL^b$; Gould, 1966) and logarithmic transformations. The relative condition factor (K_n, Le Cren, 1951) was also calculated by using the follow relationship: $K_n = W_{(meas)}/[aL^b]$ where $W_{(meas)}$ represented our measured weights and $[aL^b]$ represented weight estimated by means allometric equations. Feeding was studied by calculating the daily rate of feeding (f; Tsevis et al., 1992) according the equation:

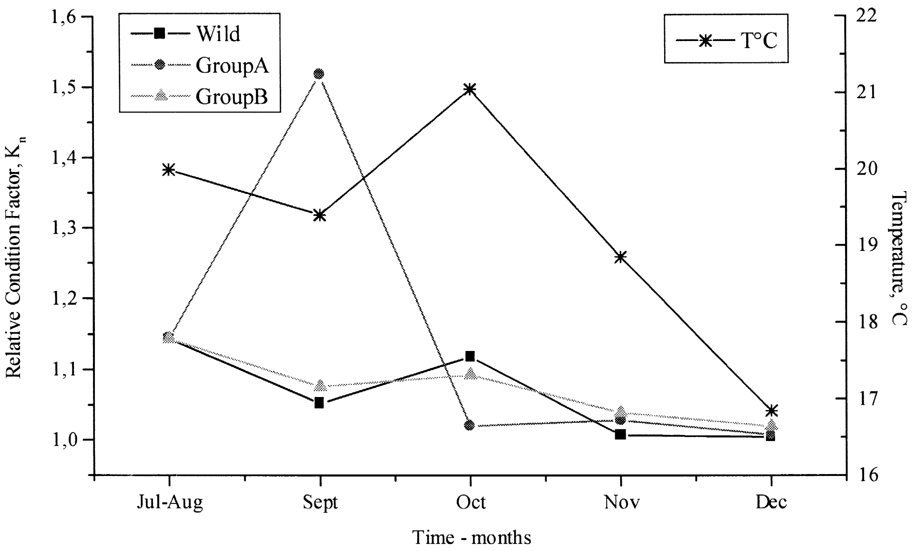

Fig. 2. Monthly trends of relative condition factor (K_n; Le Cren, 1951) of *Seriola dumerili* in cage culture and the wild, relative to water temperature changes during cultivation.

$f = F_t^* 100/[t^*(W_0 + W_t + W_d)/2]$, where F_t was the total food consumption, W_0 and W_t were respectively the initial and final biomass, W_d the dead biomass and t the time in days and the food conversion ratio (FCR; Carter et al., 1994) according the follow equation: $FCR = FT_{DW}/(W_0 - W_t)$ where FT_{DW} was total dry food and W_0 and W_t were the same as above. The Kruskall–Wallis test (Sokal and Rohlf, 1981) was used to ascertain differences in growth performance.

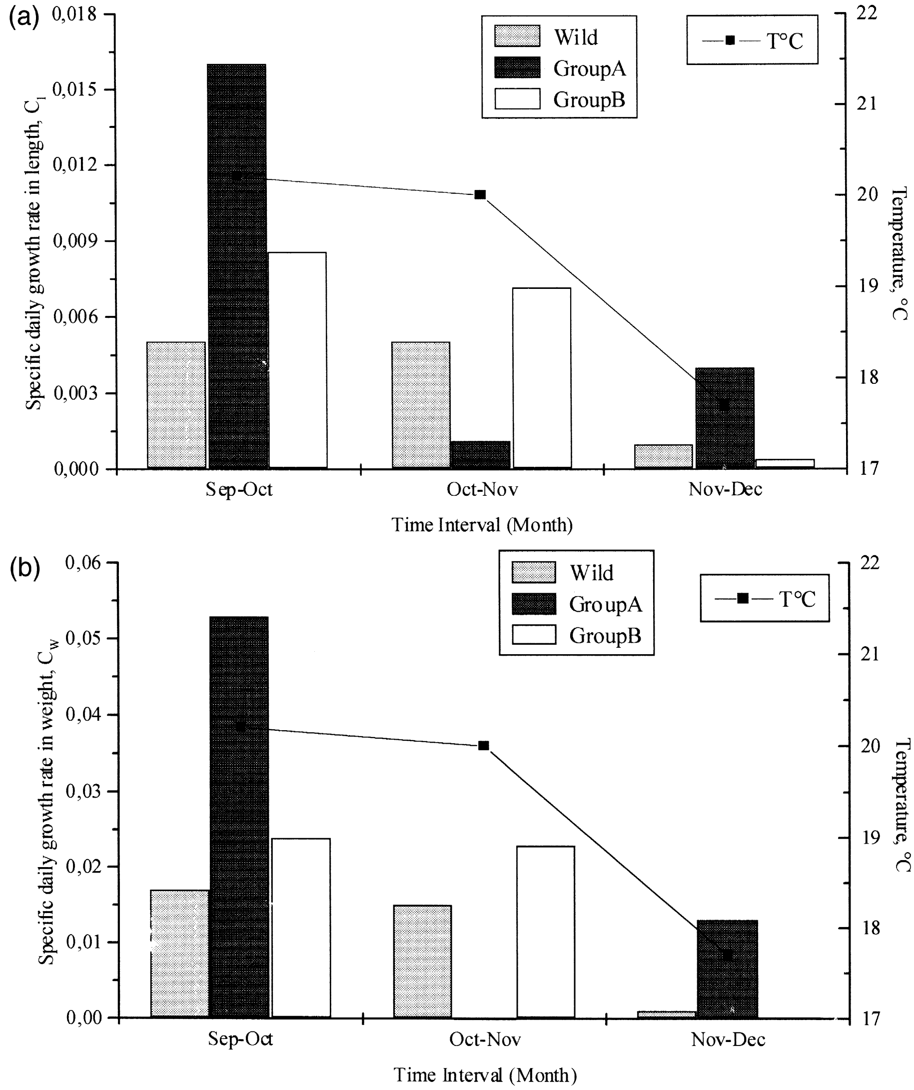

Fig. 3. Specific daily growth rates in length (a) and wet weight (b) relative to the temperature trend for the 3 groups of fish in cultivation.

3. Results

Water temperature at the surface ranged from 16.7°C (autumn–winter) to 22°C (summer) (mean value = 19.58 ± 2.03°C) and salinity was between 37.5 psu (autumn–winter) and 38.1 psu (summer) (mean value = 37.88 ± 0.19 psu). The thermocline was observed to be at a depth of approximately 10–12 m for the whole summer period until September.

3.1. Cultivation phase

3.1.1. Growth

Fig. 1a and b show the monthly trend of total length and total wet weight of the 3 groups of *Seriola dumerili* during the experimentation period. Although there were no significant differences in wet weight ($H_{TWW} = 6.93$; $P > 0.05$; $n = 12$), group A reached the largest size. Significant differences were, however, detected in total length ($H_{TL} = 7.93$; $P < 0.05$; $n = 12$). The overlapping of the growth curves for the wild population and group B was also confirmed by the relative condition factor (K_n) trend (Fig. 2).

The relative condition factor showed that increases in weight and length did not lead to a corresponding increase in this factor: when the weight increased from 158 g to 777 g (October, group A), the condition factor decreased from 1.04 to 1.01. These values were lower than those of the wild population. These group A specimens increased a great deal in size and represented a departure from the general trend shown by the wild population.

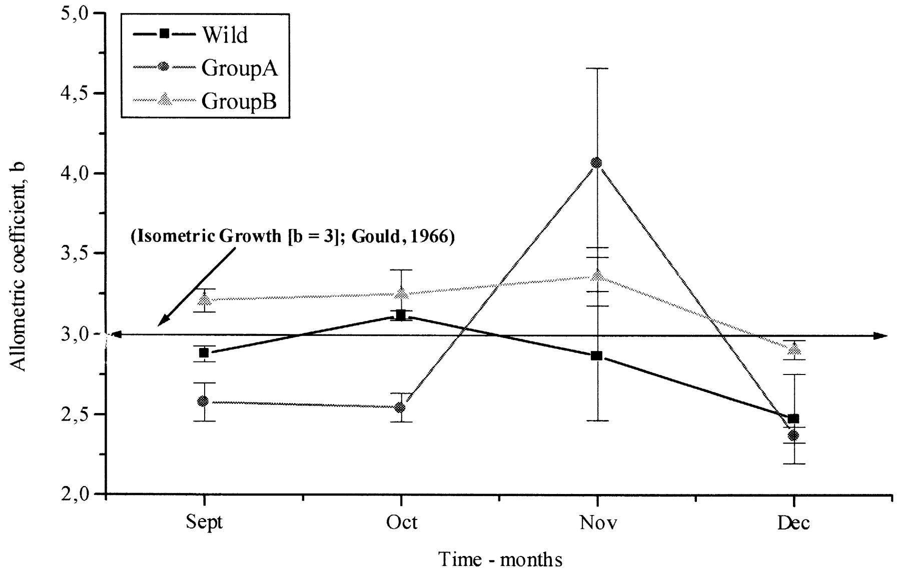

Fig. 4. Monthly trend of allometric coefficient (b = slope of allometric regression) of fish in cage and wild in comparison with a typical trend as indicated in Gould (1966).

Table 1
Diet composition and biochemical features of the main species composing fish scrap supplied to the *Seriola dumerili* of group A. Biochemical composition of food derived by Bono et al., 1992

Species	% Composition in diet	Total amount of food in dry weight (kg)	% Protein	% Lipid	% Carbohydrate	% Ash
Scomber scomber	46.38	496.5	48.51	31.67	3.99	15.83
Boops boops	16.93	157.3	59.66	18.5	7.36	14.48
Trachurus trachurus	15.51	155.9	73.44	4.16	1.24	21.16
Spicara sp.	3.865	29.54	68.81	2.91	0.67	27.61
Leptidotrigla cavillone	2.68	19.63	81.19	4.93	0.96	12.92
Merluccius merluccius	2.623	18.27	85.13	3.81	0.64	10.42
Lophius budegassa	1.128	8.316	69.63	2.68	0.77	26.92
Arnoglussus laterna	0.31	2.349	67.88	8.97	0.98	22.17
Lepidopus caudatus	0.282	2.464	65.38	13.53	1.12	19.97
Argentina sphyraena	0.141	1.106	75.69	13.06	0.74	10.51
Capros aper	0.141	1.241	61.56	16.84	1.16	20.44
Gnathophis mystax	0.085	0.648	80.19	3.65	0.94	15.22
Other species	9.929	74.43	69.76	10.39	1.71	18.14
Total amount of food	100	967.6	–	–	–	–

Table 2
Diet composition and biochemical features as reported by Hendrix (Italy) of pelletted food supplied to *Seriola dumerili* of group B

	Pellet size (mm)		
Composition	3.00	4.00	8.00
% H_2O	8.20	9.00	10.0
% Protein	47.0	47.5	48.0
% Lipid	18.0	18.0	10.5
% Cellulose	1.30	1.00	1.00
% Ash	12.6	11.2	11.0

No significant differences were shown in specific growth rate between the three groups ($H_{CL} = 5.62$; $P > 0.05$; $n = 12$; $H_{CWW} = 4.85$; $P > 0.05$; $n = 12$) (Fig. 3a, b), even though group A showed a peak in September–October and November–December. The two other populations showed a constant trend, except for the months of November–December when the rate reached minimum value.

The coefficient b trend of the allometric relationship between TL and T_{WW} (Fig. 4) as an index of growth performance (Gould, 1966) displayed the typical trend for the wild population at around a mean value of 2.80 ± 0.26. Group A gave similar results with a mean value of 2.82 ± 0.71 except in November when b reached an anomalous value of 4, while group B showed a different trend with higher values (mean $= 3 \pm 0.33$).

3.1.2. Feeding features

Tables 1 and 2 (data according to Bono et al., 1992 and Trouvit, respectively) report the diet and chemical composition of the food used in cultivation, while Table 3a–b show the feeding features for the two groups of *S. dumerili*. The total amount of food supplied to group A was 3545 kg (967.6 kg dry matter) during the period of cultivation. The diet was principally composed of *Scomber scomber* (46.38%), *Boops boops*

Table 3
(a) Feeding parameters of the *Seriola dumerili* of group A

Month	Total wet biomass (kg)	Total amount dry weight of food (kg)	Food supplied as a function body weight (%)	Density ($kg\ m^{-3}$)	Daily rate of feeding
SEPT	126.40	93.14	9.00	1.68	3.01
OCT	621.60	267.17	5.25	8.28	1.90
NOV	619.20	261.07	5.15	8.26	1.12
DEC	919.20	346.17	4.60	12.30	1.20
b. Feeding parameters of the Seriola dumerili of group B					
SEPT	108.00	117.86	4.00	1.44	4.29
OCT	224.00	244.45	4.00	2.99	3.93
NOV	456.00	373.22	3.00	6.08	2.93
DEC	460.80	502.86	4.00	6.14	2.93

(16.93%) and *Trachurus trachurus* (15.51%), with these three species representing over 78% of the total amount of food consumed. Group A reached a total wet biomass of 919.2 kg, a final density in the cage of 12.3 kg/m^3 and a food conversion ratio of 1.22. The daily feeding rate was higher during September (3.01% T_{WW}), decreasing to 1.20% T_{WW} in December.

The total amount of food supplied to group B was 1362 kg (1,238 kg dry matter). Group B fish reached 461 kg in total biomass, a final density of 6.14 kg/m^3 and a food conversion ratio of 3.51. The daily feeding rate was found to be more constant during the cultivation period, dropping slightly from September (4.29% T_{WW}) to December (2.93% T_{WW}).

4. Discussion

In this study the survival rate of captured juveniles was 100%, compared with 98% reported by Porrello et al. (1993) and 80% by Cavaliere et al. (1989). Mortality ($n = 25$; 3.12%) was then observed only at the beginning of the experiment (in September) in the pellet-fed group. This was probably due to acclimatization and not to the cultivation process. Temperature changes were not observed to have a negative influence, contrary to the findings of Garcia-Gomez (1993).

The two diet types did not significantly affect the growth trends, although group A reached a larger size than the other two groups. Similar findings were observed in *Seriola quinqueradiata* fed both with different pellet types (Shimeno et al., 1993) and with raw fish (Watanabe et al., 1993).

Specific daily growth rate, the condition factor and the allometric relationship did not show a correlation with temperature because the cages were located beneath the thermocline where only small variations in temperature occurred ($\Delta T + 4$°C). In contrast, wide monthly changes in chemical–physical variables have been shown to have an important role in growth in floating cages and tanks (Garcia-Gomez, 1993; Porrello et al., 1993).

The results of other experiments carried out with *Seriola dumerili* in the western Mediterranean area are reported in Table 4. Different results were obtained from experiments in tanks by Garcia-Gomez (1993). Growth curves of pellet-fed *S. dumerili* were similar to those of the wild population, although the maximum size was not significantly different.

The growth trend and the maximum size of group A were better than those obtained in floating cages (Giovanardi et al., 1984; Porrello et al., 1993) and tanks (Cavaliere et al., 1989; Garcia-Gomez, 1993; Greco et al., 1993). The food conversion ratio obtained with pellets was high despite their elevated nutritional value (Garcia-Gomez, 1993) and higher compared to the ratio of group A. Group A was fed with fish scraps which, despite their high water content, were found to be more nutritious. Food scraps produced a food conversion ratio that was lower than those reported in the literature.

The greatest degree of homogeneity in the class sizes was observed in group B (Garcia-Gomez, 1993), and this was probably due to the homogeneous size of the pellets compared to the fish scraps, which varied in weight and shape. Furthermore, the fish

Table 4
Comparing results of other experiments of cultivation of *Seriola dumerili* carried out in the Mediterranean

Site	Type of cultivation	Initial total wet weight (g)	Final total wet weight (g)	Time of cultivation (day)	Diet type	Food conversion ratio	References
Castellammare (Sicily)	Floating cage	130	670	85	Fish scraps	Not reported	Giovanardi et al., 1984
Messina (Sicily)	PVC tanks	< 100 (?)	1214	380	Fish scraps	Not reported	Cavaliere et al., 1989
Messina (Sicily)	PVC tanks	58.1	379	110	Fish scraps	3	Cavaliere et al., 1989
Coasts of Spain	PVC tanks	64	412	120	Pellets	1.80	Garcia-Gomez, 1993
Coasts of Spain	PVC tanks	64	367	120	Pellets	2.30	Garcia-Gomez, 1993
Coasts of Spain	PVC tanks	64	396	120	Fish scraps	4.89	Garcia-Gomez, 1993
Coasts of Spain	PVC tanks	64	342	90	Fish scraps	1.48	Garcia-Gomez, 1993
Messina (Sicily)	PVC tanks	106	500	300	Fish scraps	4	Greco et al., 1993
Messina (Sicily)	PVC tanks	106	392	300	Fish scraps + chicken liver	5	Greco et al., 1993
Aeolian Islands (Sicily)	Floating cage	72.7	858	120	Fish scraps	4.4	Porrello et al., 1993
Castellammare (Sicily)	Submerged cage	48	576	120	Pellets	3.51	This paper
Castellammare (Sicily)	Submerged cage	48	1149	120	Fish scraps	1.22	This paper

scraps may have produced competitive behaviour and a degree of territoriality among the specimens, resulting in a marked heterogeneity in class sizes.

This study has shown that cages are easy to use and are compatible with the work of small-scale fishermen. The low investment costs, limited breeding period and suitability for small-scale fishing all make this a useful way to convert coastal fishing. The absence of a visual impact from these cages also makes them an acceptable proposal for sea parks and protected areas.

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