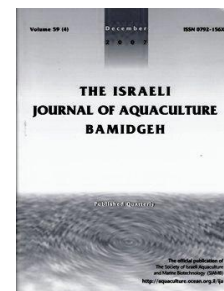


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Offshore Farming of the Mediterranean Amberjack (*Seriola dumerili*) in the Northeastern Mediterranean

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Key words: *Seriola dumerili*, offshore, farming, feeding, Mediterranean

Abstract

The growth rate, survival, and feeding parameters of Mediterranean amberjack (*Seriola dumerili* Risso, 1810) cultivated in offshore cages in the Gulf of İskenderun (Hatay, Turkey) were investigated from July 2006 to March 2008. Two offshore cages (339 m³) were placed at a depth of 10 m in a sheltered area 500 m off the coast. Juveniles (101.97±14.54 g), caught with seine nets 400-1200 m from the coast, were stocked in the cages at 250 per cage. Fish in one cage, Group A, were fed commercial pellets for all 20 months whilst fish in the second cage, Group B, were fed pellets for the first 16 months and frozen sardines for the following four. The mean live weight, survival, feed conversion ratio, daily feed consumption, and water quality parameters were recorded monthly. Group B reached a significantly ($p<0.05$) greater weight (2785.00±64.91 g) than Group A (2441.14±38.13 g). Food conversion ratios ranged 1.16-2.46 for group A and 1.10-2.28 for group B, low when compared with other studies on amberjacks in the Mediterranean. Average mortality was 25%, due to a *Zeuxapta seriolae* (Monogenea: Heteraxinidae) infection in December 2006 (20%) and fish handling for measurement in June 2007 (~5%). The farmed amberjacks had significantly higher protein and lipid contents than their wild counterparts at the end of the 20-month feeding period. Amberjacks found frozen sardines more appealing than pellets, especially during the winter. In conclusion, it is advised to feed Mediterranean amberjack frozen sardines or other trash fish during the winter grow-out period. Their rapid growth rate, as well as their adaptability to farming, make offshore net cages a promising system for the aquaculture of this species.

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Introduction

The Mediterranean amberjack, *Seriola dumerili* (Risso 1810), also referred to as the greater amberjack, is a carnivorous pelagic fish (Carangidae) that satisfies the criteria for selection of new aquaculture species (Marino et al., 1995), i.e., it has a rapid growth rate (Andaloro et al., 1992), easily adjusts to captivity, has excellent flesh quality, and is sold for a high market price (Nakada, 2000). It is distributed throughout tropical and subtropical regions except the Pacific Ocean (Laroche et al., 1984). In the eastern Atlantic, this species is distributed from the Bay of Biscay to South Africa, whereas in the western Atlantic, it inhabits the area from Nova Scotia to Brazil, including the Gulf of Mexico, the Caribbean, and Bermuda (Fischer, 1978). Amberjack is abundant in the Mediterranean area, except in the Black and north Adriatic Seas, (Andaloro et al., 1992).

The morphological and ecological characteristics of *S. dumerili* are similar to *S. quinqueradiata* which has been widely reared in Japan for over 25 years. *Seriola dumerili* is also reared in Japan and is imported from China to Japan. It has a high growth rate in the natural environment (Thompson et al., 1999) and in culture conditions (Jover et al., 1999; Mazzola et al., 2000). Hence, it has become one of the most important aquaculture species in the Mediterranean region as well as in Japan (Nakata, 2000; Takakuwa et al., 2006). It adapts easily to a captive environment but reproduction in culture conditions is difficult, although it has recently been successfully reproduced in Greece and Malta and Japanese scientists have successfully reared larvae since 1987 (Tachihara et al., 1993).

The commercial culture of *S. dumerili* in the Mediterranean is based on capture of wild juveniles that are fattened to marketable size (Lazzari et al., 2000; Pastor et al., 2000). On-growing in Mediterranean countries (Spain, Italy) as well as Japan generally occurs in net cages, using raw, fresh, frozen, or chopped fish (*Sardinella aurita*, *Boops boops*, *Trachurus trachurus*, *Spicara maena*). In the Mediterranean, juveniles have been reared in concrete tanks (Cavaliere et al., 1989; Garcia et al., 1993) and inshore net cages (Porrello et al., 1993). This investigation presents results of the cultivation of amberjack in offshore cages using simple low-cost installation techniques. Growth rate, survival, and feeding parameters of two groups of fish fed different diets in the northeastern Mediterranean were tested.

Materials and Methods

Feeding trials were carried out between July 2006 and April 2008 in the Gulf of İskenderun (Hatay, Turkey) in a sheltered area 500 m off the coast. Two offshore cages of 339 m³ (12 m diameter × 3 m, 12 and 18-mm mesh for juveniles and adults, respectively) were moored onto artificial reefs at a depth of 10 m. Together with local fishermen, the research team caught juveniles (101.97±14.54 g) during the summer of 2006 using seine nets with 14-16 mm mesh, 400-1200 m from the coast. The fish were weighed and placed in a 2-m³ PVC tank on the fishing boat. The tank was equipped with a flow-through seawater system during transport to the cages. Two hundred and fifty fish were stocked into each cage as soon as possible.

The juveniles were fed three diets composed of frozen sardines (*Sardina pilchardus*) and pellets at rates of 75/25, 50/50, and 25/75 for the first, second, and third months (July, August, and September 2006, respectively) to wean them to the dry commercial diet. Frozen sardines were initially offered in small minced pieces (heads removed) but, as the juveniles grew, the sardines were chopped to adequate sizes. After weaning, fish in one cage, Group A, were fed commercial pellets for 17 months and fish in the second cage, Group B, were hand-fed commercial pellets for 13 months (from November 2006 to December 2007) and frozen sardines for the next 4 months. Fish were fed to satiation three times a day throughout the experimental period. The daily amount of food administered was recorded for both groups throughout the experimental period.

The mean body weight, specific growth rate, survival, feed conversion ratio, and total amount of food administered (as a function of body weight, %) were calculated on a monthly basis. Growth performance data were analyzed as follows: daily specific growth rate (%/day) in somatic live weight as $SGR = 100 [(W_t/W_0)^{1/t} - 1]$, where W_t = weight on

day t , W_0 = weight on day 0, and t = time elapsed in days; and the feed conversion ratio (FCR) as the amount of food consumed (dry weight in g) divided by the growth in biomass (wet weight in g) for a specific time period. Water quality parameters were measured on a daily basis, dissolved oxygen and temperature with a YSI 52 model oxygen meter (Yellow Springs Instruments Co., Ohio, USA), pH with an ORION 420A model, and salinity with an ATAGO hand refractometer.

At the end of the study, standard laboratory methods (AOAC, 1990) were used to determine the proximate compositions of fillets of the cultured and wild amberjacks as follows: moisture was determined by oven-drying at 105°C for 24 h, crude protein (N x 6.25) by the Kjeldahl method, and crude ash by combustion in a muffle furnace at 550°C for 16 h. Total lipid concentration was determined by the extract with chloroform-methanol method (Bligh and Dyer, 1959). Differences among groups in growth performance and proximate fillet composition were tested with Kruskal-Wallis one-way analysis of variance by ranks (SPSS 10.0 for Windows) followed by the Duncan non-parametric multiple comparison procedure (Zar, 1984).

Results

Monthly temperature, salinity, dissolved oxygen, and pH are shown Fig. 1. Water temperature at the surface ranged 16.5-19.0°C in December-February, 17.0-20.0°C in March-May, 24.5-29.0°C in June-August, and 24.0-28.0°C in September-November. For the same months, salinity was 35.5-36.1, 36.4-37.4, 37.3-37.8, and 36.2-37.1, dissolved oxygen 8.4-8.7, 7.7-8.1, 6.7-7.2, and pH 8.4-8.7, 8.4-8.5, 8.6-8.7, and 8.0-8.3.

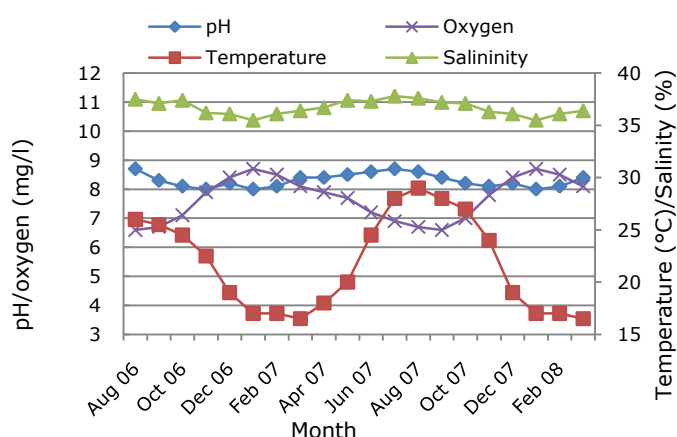


Fig. 1. Monthly salinity, pH, dissolved oxygen, and temperature in offshore cages used to cultivate the Mediterranean amberjack (*Seriola dumerili*).

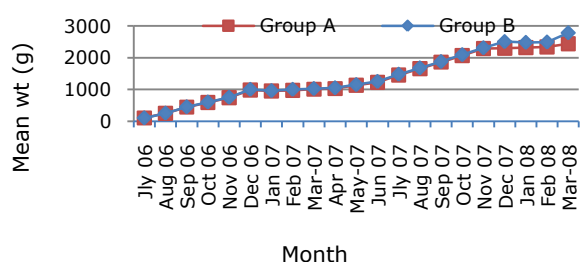


Fig. 2. Monthly average live weight of *Seriola dumerili* fed pellets only (Group A) or pellets and sardines (Group B).

The wild Mediterranean amberjack juveniles adapted well to captivity conditions and accepted the food provided from their arrival in the offshore culture system onwards. They had a high growth rate throughout the 20 months of rearing. Fish in Group B (2785.00 ± 64.91 g) reached a higher weight ($p < 0.05$) than those in Group A (2441 ± 38.13 g) by the end of the study (Fig. 2).

At the end of the trial, mortality was 24.8% and 23.2% in Groups A and B, respectively, due to infection (20%) by *Zeuxapta seriolae* (Monogenea: Heteraxinidae) in December 2006 and handling for monthly measurements (~5%) in June 2007 (Table 1).

Survival and feeding parameters did not differ significantly between groups. There were no significant differences in daily live weight gain or SGR except at the end of the experiment (March 2008). The feeding rates were constant, except when they dropped in September 2006. SGR was lowest in December 2006 due to the low water temperature and *Z. seriolae* infection (Fig. 3). FCR did not significantly differ and decreased with the increasing water temperature, as expected (Fig. 4).

Table 1. Average weight, survival, and feeding parameters of Mediterranean amberjack fed a commercial feed for 20 months (Group A) or a commercial feed for 16 months and frozen sardines for the remaining four months (Group B).

| Month | Mean wt±SD | | Wt range (g) | | Fish (n) | | Survival (%) | | Feed conversion ratio | | Total food (%/body wt) | |
|--------|----------------------------|----------------------------|--------------|-----------|----------|-----|-----------------|-----------------|-----------------------|------|------------------------|------|
| | A | B | A | B | A | B | A | B | A | B | A | B |
| Aug 06 | 246.72±21.62 | 250.11±21.98 | 195-285 | 200-300 | 250 | 250 | 100 | 100 | 2.46 | 2.23 | 8.20 | 7.43 |
| Sep 06 | 442.61±26.00 | 450.27±24.79 | 400-490 | 400-500 | 250 | 250 | 100 | 100 | 1.16 | 1.10 | 3.86 | 3.66 |
| Oct 06 | 592.16±25.66 | 600.00±27.66 | 545-648 | 550-650 | 250 | 250 | 100 | 100 | 1.85 | 1.81 | 6.16 | 6.03 |
| Nov 06 | 742.22±27.61 | 750.00±28.78 | 695-800 | 700-800 | 250 | 250 | 100 | 100 | 2.35 | 2.28 | 7.83 | 7.60 |
| Dec 06 | 984.72±34.01 | 1000.50±47.16 | 840-1146 | 850-1150 | 200 | 200 | 80 ¹ | 80 ¹ | 1.94 | 1.90 | 6.46 | 6.30 |
| Jan 07 | 948.88±33.27 | 960.00±35.86 | 810-1070 | 860-1060 | 200 | 200 | 100 | 100 | 2.03 | 1.99 | 6.76 | 6.63 |
| Feb 07 | 974.72±34.89 | 1000.05±64.94 | 820-1150 | 850-1190 | 200 | 200 | 100 | 100 | 2.21 | 2.15 | 7.36 | 7.10 |
| Mar 07 | 1008.00±39.75 | 1025.00±35.35 | 900-1095 | 925-1100 | 200 | 200 | 100 | 100 | 2.08 | 2.02 | 6.93 | 6.73 |
| Apr 07 | 1027.22±52.57 | 1050.00±40.00 | 925-1100 | 950-1100 | 200 | 200 | 100 | 100 | 1.96 | 1.93 | 6.53 | 6.43 |
| May 07 | 1130.55±54.10 | 1150.00±53.74 | 1040-1250 | 1050-1250 | 200 | 200 | 100 | 100 | 1.97 | 1.95 | 6.56 | 6.50 |
| Jun 07 | 1223.88±56.58 | 1250.00±55.27 | 1127-1305 | 1150-1300 | 188 | 192 | 93 ² | 95 ² | 1.91 | 1.90 | 6.36 | 6.33 |
| Jul 07 | 1453.38±61.42 | 1478.16±57.84 | 1350-1582 | 1378-1578 | 188 | 192 | 100 | 100 | 1.89 | 1.85 | 6.30 | 6.16 |
| Aug 07 | 1657.27±57.40 | 1676.00±54.76 | 1568-1774 | 1579-1779 | 188 | 192 | 100 | 100 | 1.87 | 1.86 | 6.23 | 6.20 |
| Sep 07 | 1860.55±62.48 | 1877.00±56.20 | 1795-1965 | 1800-1954 | 188 | 192 | 100 | 100 | 1.91 | 1.90 | 6.36 | 6.33 |
| Oct 07 | 2067.77±54.92 | 2095.00±53.85 | 1169-2198 | 1195-2195 | 188 | 192 | 100 | 100 | 1.92 | 1.89 | 6.40 | 6.30 |
| Nov 07 | 2287.66±63.47 | 2313.05±56.23 | 2205-2421 | 2200-2426 | 188 | 192 | 100 | 100 | 1.95 | 1.90 | 6.50 | 6.33 |
| Dec 07 | 2297.28±35.02 ^a | 2508.38±41.31 ^b | 2235-2520 | 2450-2567 | 188 | 192 | 100 | 100 | 2.04 | 1.95 | 6.80 | 6.50 |
| Jan 08 | 2318.55±29.31 | 2483.00±25.91 | 2285-2525 | 2395-2530 | 188 | 192 | 100 | 100 | 2.16 | 1.99 | 7.20 | 6.63 |
| Feb 08 | 2339.69±25.40 | 2594.22±21.80 | 2300-2600 | 2462-2610 | 188 | 192 | 100 | 100 | 2.25 | 2.06 | 7.50 | 6.86 |
| Mar 08 | 2441.14±38.13 ^a | 2785.00±64.91 ^b | 2380-2693 | 2540-2820 | 188 | 192 | 100 | 100 | 1.91 | 2.03 | 6.36 | 6.86 |

Mean values in the same row with different superscripts significantly differ at $p < 0.05$.

¹ mortality due to *Zeuxapta seriolae* infection

² mortality due to handling during monthly fish measurement

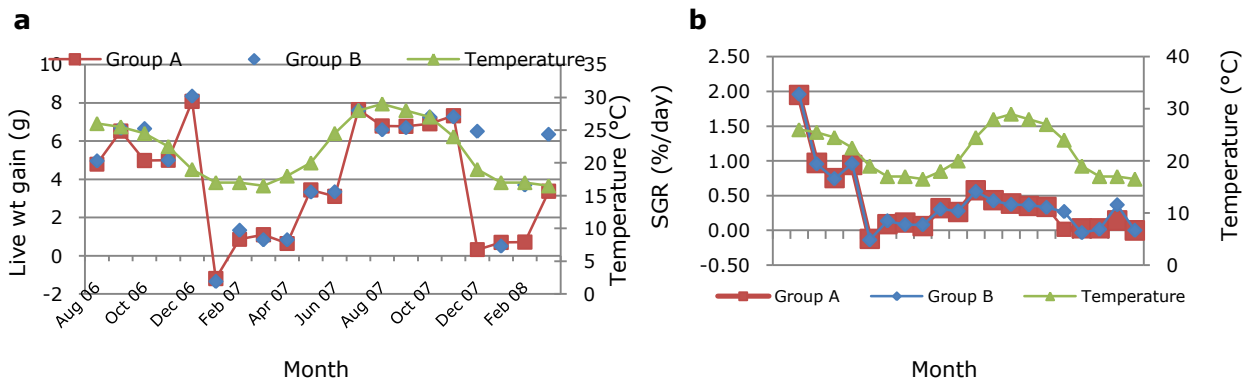


Fig. 3. (a) Daily live weight gain and (b) specific growth rate of Mediterranean amberjack (*Seriola dumerili*) fed commercial pellets for 20 months (Group A) or commercial pellets for 16 months and frozen sardines for 4 months (Group B).

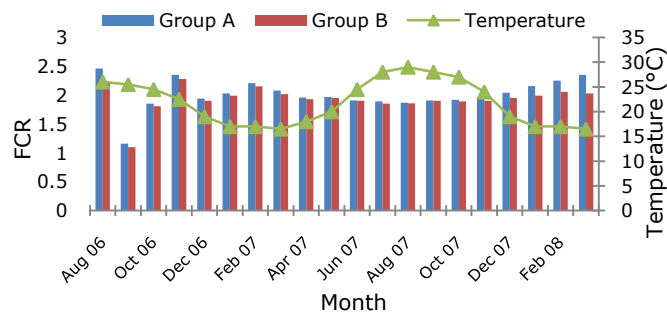


Fig 4. Feed conversion ratios of Mediterranean amberjack fed commercial pellets (Group A) or pellets and sardines (Group B).

The FCR was low in comparison to other studies on amberjacks in the Mediterranean (Table 2). At the end of the feeding trial, fillets of the cultured amberjacks had significantly higher protein and lipid contents than those of wild amberjacks captured by local fishermen in the same area (Table 3). On the contrary, moisture and ash contents of the wild amberjacks were higher than those of their farmed counterparts ($p < 0.05$).

Table 2. Comparison of results with other amberjack cage experiments in the Mediterranean.

| Site | Cage system | Initial wt (g) | Final wt (g) | Cultivation period (days) | Diet | FCR | Reference |
|--------------------------|-------------|----------------|--------------|---------------------------|---------------------------|------|------------------------|
| Castellammare, Sicily | Floating | 130 | 670 | 85 | Fish scraps | - | Giovanardi et al. 1984 |
| Aeolian Islands, Sicily | Floating | 73 | 858 | 120 | Fish scraps | 4.40 | Porrello et al. 1993 |
| Castellammare, Sicily | Submerged | 48 | 576 | 120 | Pellets | 3.51 | Mazzola et al. 2000 |
| Castellammare, Sicily | Submerged | 48 | 1129 | 120 | Fish scraps | 1.22 | Mazzola et al. 2000 |
| İskenderun Hatay, Turkey | Off-shore | 102 | 2441 | 600 | Pellets | 2.01 | This paper |
| İskenderun Hatay, Turkey | Off-shore | 102 | 2785 | 600 | Pellets & frozen sardines | 1.93 | This paper |

Table 3. Proximate compositions (%) of farmed and wild amberjack, other fish species, and feeds.

| | Moisture | Crude protein | Total lipid | Crude ash | Reference |
|----------------------------------|------------|---------------|-------------|-----------|--------------------------|
| Farmed <i>S. dumerili</i> | 73.53±0.20 | 21.86±0.41 | 2.89±0.46 | 1.10±0.06 | This study |
| Wild captured <i>S. dumerili</i> | 76.51±0.11 | 19.61±0.47 | 2.03±0.05 | 1.33±0.07 | This study |
| <i>Sparus aurata</i> | 78.20±1.79 | 18.08±0.71 | 9.80±1.36 | 1.37±0.08 | Grigorakis et al. 2003 |
| <i>Dicentrarchus labrax</i> | 70.30 | 21.80 | 7.69 | 1.32 | Kyranas & Lougovois 2002 |
| Commercial diet | 9.25 | 45.00 | 22.50 | 9.00 | - |
| Frozen sardine | 75.83 | 20.05 | 0.99 | 3.04 | Skaramuca et al. 2001 |

Discussion

The mortality rates were 24.8% in Group A and 23.2% in Group B. The high mortality resulted primarily from a *Zeuxapta seriolae* infection during December 2006, which accounted for 20% mortality. During the infection, the cages were subjected to formalin baths - a 300 ppm solution for 1 h during every week of infection. This treatment is typically used in aquaculture to exterminate monogeneans. The same procedure was followed before winter in 2007. In addition, the commercial diet was fortified by adding vitamin C. No further mortality occurred due to *Z. seriolae* infection after December 2006, indicating that the formalin bath treatments and vitamin C supplementation were effective together. The second incidence of mortality occurred during the monthly fish measurements in June 2007.

The wild captured Mediterranean amberjack juveniles adapted well to the cage conditions, accepting the provided food from stocking in the offshore culture system onwards. The growth rate was high throughout the 20 months of rearing except during winter. During adaptation to the commercial diet (July-September 2006), the fish in both groups accepted the food readily and attained higher specific growth rates than in other months. After adaptation, from winter 2007-8, group B reached a significantly larger size than group A, possibly because the amberjacks were observed to feed more readily on the frozen fish than on the commercial pellets.

Wide monthly changes in physico-chemical variables have a significant effect on amberjack growth in floating cages and tanks (Porrello et al., 1993). In our study, changes in growth performance and feed conversion ratios were closely related to water temperature. The growth performance can be divided into two distinct periods: April-November (high) and December-March (low). Different results were obtained in tanks by Garcia et al. (1993) and Skaramuca et al. (2001). The growth and maximum size of Group B were comparable to those obtained in floating cages (Giovanardi et al. 1984; Porrello et al., 1993) and tanks (Cavaliere et al., 1989; Greco et al., 1991). As expected, feed conversion ratios in both groups were higher in the winter than in the warmer months due to bad weather conditions and lower water temperatures. In general, FCR values were better than in earlier attempts conducted in the Mediterranean, except for those of Mazzola et al. (2000). Earlier reports support our findings that amberjack growth performance and daily rate of feeding decrease in autumn and winter (Mazzola et al., 2000; Skaramuca et al., 2001). During the high growth period, feed conversion rates were lower as long as the temperature was above 19°C. In the low growth period, when temperatures were relatively low (<19°C), the FCR rose. The difference between these

two periods should be taken into account in amberjack aquaculture in the Mediterranean as these environmental conditions represent the real situation under which amberjack aquaculture will have to function.

The amberjacks in both groups had similar protein, lipid, ash, and moisture contents at the end of the experiment. Likewise, tank-reared Mediterranean amberjack fed pellets or frozen sardines had similar lipid, ash, moisture, and protein contents (Skaramuca et al. 2001). However, our amberjacks had a higher lipid content than the tank-reared amberjacks and significantly higher protein and lipid contents than wild amberjacks, indicating that Mediterranean amberjacks fed a commercial diet attain higher protein and lipid contents than wild and tank-reared specimens. Farmed Mediterranean amberjack are, thus, high-quality fish with a high percent of protein comparable to that of other farmed species and wild counterparts.

In conclusion, Mediterranean amberjack can be successfully reared in off-shore cage systems and has great aquaculture potential in the northeastern Mediterranean. In the winter, the juveniles consumed the frozen sardines more readily than the commercial feed, thus it is advised to use frozen sardines and/or semi-moist pelleted diets during the winter grow-out period for better feed intake and growth performance. Further research is certainly needed for sustainable culture of Mediterranean amberjack especially in the following areas: feeding strategy, reproductive control, sustainable larval rearing, and nutritional requirements.

Acknowledgements

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