# Recent experiences on the culture of rabbitfish Siganus rivulatus in Cyprus

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# Recent experiences on the culture of rabbitfish *Siganus rivulatus* in Cyprus

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**SUMMARY –** The rabbitfish (*Siganus rivulatus*), is one of the species selected by the Department of Fisheries for the diversification of aquaculture in Cyprus. It is a euryhaline species which came in to the Mediterranean through the Suez canal. It is highly appreciated, a vegetarian fish feeding under culture conditions on terrestrial plants as well, such as clover and it accepts easily pelleted dry diets. Data from fish reared in the Department's Marine Aquaculture Research Station at Meneou show that *S. rivulatus*, of both sexes, have matured gonads at the age of one year old and it is assumed that it could spawn at this age. The off season spawning of *S. rivulatus* was achieved at the Department's Research Station in 1998. Using environmental manipulation *S. rivulatus* broodstock was induced to sexual maturity and spawned once a month, from March to June. The natural spawning period of this species is in the summer time, June to September, once a month around full moon. Larval rearing was undertaken using several culture methods and techniques. The main problem encountered was at the early feeding of the larvae (day 2-day 6) because of the small size of their mouth. Various sizes of enriched rotifers, (*Brachionus plicatilis*) including super small (SS) strains (90-150 µm) in densities of up to 10/ml, in combination with several species of phytoplankton (*Chlorella, Tetraselmis, Nanochloris, Dunaliella, Chlorococcum*), or separately, were tried for larval feeding starting from day 2, however, with very limited survival. An application of the mesocosm technology (semi extensive hatchery technology) has given slightly better results. Larval growth was very fast. On day 18 dry food was given and on day 32 the weaned fry had an average length of 2.5 cm.

**Key words:** *Siganus rivulatus*, Cyprus aquaculture, rabbitfish culture, rabbitfish.

***RESUME –*** *"Expériences récentes concernant la culture du sigan marbré* Siganus rivulatus *à Chypre". Le sigan marbré (*Siganus rivulatus*) est l'une des espèces sélectionnées par le Département des Pêches pour la diversification aquacole à Chypre. Il s'agit d'une espèce euryhaline qui est entrée en Méditerranée à travers le canal de Suez. Elle est fortement appréciée, étant un poisson végétarien qui s'alimente en conditions d'élevage de plantes terrestres telles que le trèfle et qui accepte facilement des régimes secs granulés. Des données provenant de poissons élevés au Département de la Station de Recherches en Aquaculture Marine à Ménéou montrent que* S. rivulatus*, chez les deux sexes, ont atteint la maturité des gonades à l'âge de un an et on présume qu'ils peuvent frayer à cet âge. La ponte à contre-saison de* S. *rivulatus a été réalisée au Département de la Station de Recherches en 1998. En utilisant la manipulation environnementale, on a induit la maturation sexuelle des géniteurs de* S. *rivulatus et ils ont frayé une fois par mois, de mars à juin. La période naturelle de fraye de cette espèce est l'été, de juin à septembre, une fois par mois aux alentours de la pleine lune. La culture larvaire a été entreprise en utilisant plusieurs méthodes et techniques de culture. Le problème principal rencontré se situait au début de l'alimentation des larves (jour 2 à jour 6) à cause de la petite taille de leur bouche. Plusieurs tailles de rotifères enrichis (*Brachionus plicatilis*) y compris des souches ultra-petites (90-150 µm) à des densités de jusqu'à 10/ml, en combinaison avec plusieurs espèces de phytoplancton (*Chlorella*, Tetraselmis, Nanochloris, Dunaliella, Chlorococcum*), ou séparément, ont fait l'objet d'essais d'alimentation larvaire commençant le jour 2, avec cependant très peu de survie. Une application de la technologie du mésocosme (technologie d'écloseries semi-extensives) a donné des résultats légèrement meilleurs. La croissance larvaire a été très rapide. Au jour 18 des aliments secs furent distribués et au jour 32 les alevins sevrés avaient une longueur moyenne de 2,5 cm.*

***Mots-clés :*** Siganus rivulatus*, aquaculture à Chypre, élevage du sigan marbré, sigan marbré.*

## Introduction

The rabbitfish *Siganus rivulatus* is a Lessepsian migrant (Ben-Tuvia, 1964) which established itself successfully in the eastern Mediterranean sea. It is found mainly in the eastern Mediterranean up to the Aegean sea and along the coast of Egypt and Libya up to Tunisia in the southern Mediterranean. It is a subtropical euryhaline herbivorous fish. There are 27 species of *Siganids.* Fishes of this family are

considered of economic importance for the fishery production is several countries in the Indo Pacific and the Middle East region. In the Mediterranean the family is represented by two species, *Siganus rivulatus* and *Siganus luridus.* In Cyprus the most popular of the two is *S. rivulatus,* mainly because of its lighter body colour.

Its experimental culture by the Department of Fisheries is undertaken within the framework of a project on the diversification of aquaculture in Cyprus. *S. rivulatus* was selected because it presents high market and biological potentials. Preliminary work was undertaken 15 years ago and it was resumed during the last years with focus on the reproduction and larval rearing (Georgiou, 1986; Georgiou and Stephanou, 1991, 1997). During the last few years the *Siganid* catches from the Cyprus Fisheries are declining (Fig. 1) while the demand and consequently the price of this species remains high. The mass production of *S. rivulatus* fry under controlled conditions could contribute towards an efficient supply of the market with this species.

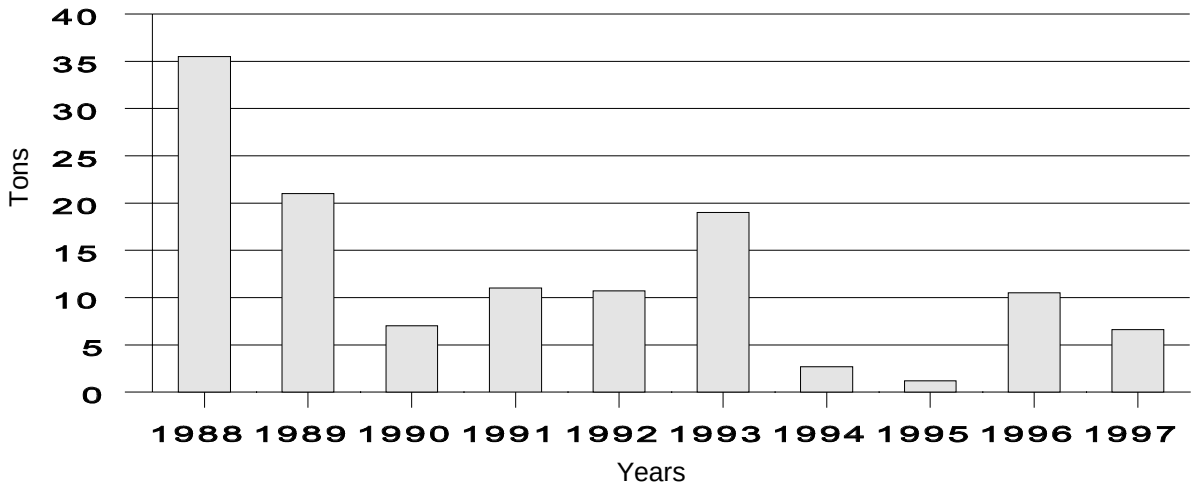


Fig. 1. Cyprus fisheries 1988-1997. Landings of *Siganids*.

*Siganids* are also cultured on an experimental scale, in other countries of the eastern Mediterranean, like in Israel and Egypt (Ben-Tuvia *et al.*, 1973; Popper *et al.*, 1973; Gundermann *et al.*, 1983; Lichatowich *et al.*, 1984), the Middle East, like the State of Bahrain (Kawahara *et al.*, 1996; Lu *et al.*, 1996; Uwate and Al-Ansari, 1996), Kuwait (Akatsu *et al.*, 1983), Saudi Arabia (Maneewong and Hazza). In the Indo Pacific region, like the Philippines, (Duray, 1986; Duray *et al.*, 1986) *Siganids,* especially *S. guttatus,* are highly esteemed fish with a high market demand and are grown on a commercial scale in polyculture systems (Pillay, 1962).

## Broodstock management

The natural spawning period of *S. rivulatus* in the eastern Mediterranean takes place in the summer months, June to September. It the Marine Aquaculture Research Station at Meneou, broodstock population, collected from the wild as juveniles and reared in the Station, spawned spontaneously in 1997, once a month during the summer, always a few days before or after full moon.

This species does not spawn repeatedly over a long period, like *Sparus aurata* for example. It gives eggs only once a month for a period of one to three days, but we are not sure if it is the same or different fish that spawn. The induced reproduction of *S. rivulatus* with the use of hormone chorionic gonadotropin (HCG) was managed in Cyprus, in previous years (Georgiou and Stephanou, 1991).

The broodstock at the Meneou Station is reared in shaded round fiberglass tanks of 10 $m^3$ at densities of 1-3 $kg/m^3$, with an open water supply system. The salinity is 39‰ and the water temperature range from 15°C in the winter to 28°C in the summer. The seawater temperature

fluctuation for 1997-1998 in shown in Fig. 2. It's nutrition consisted of dry fish food, rabbit food and fresh green vegetables, mainly clover (*Medicago sativa*).

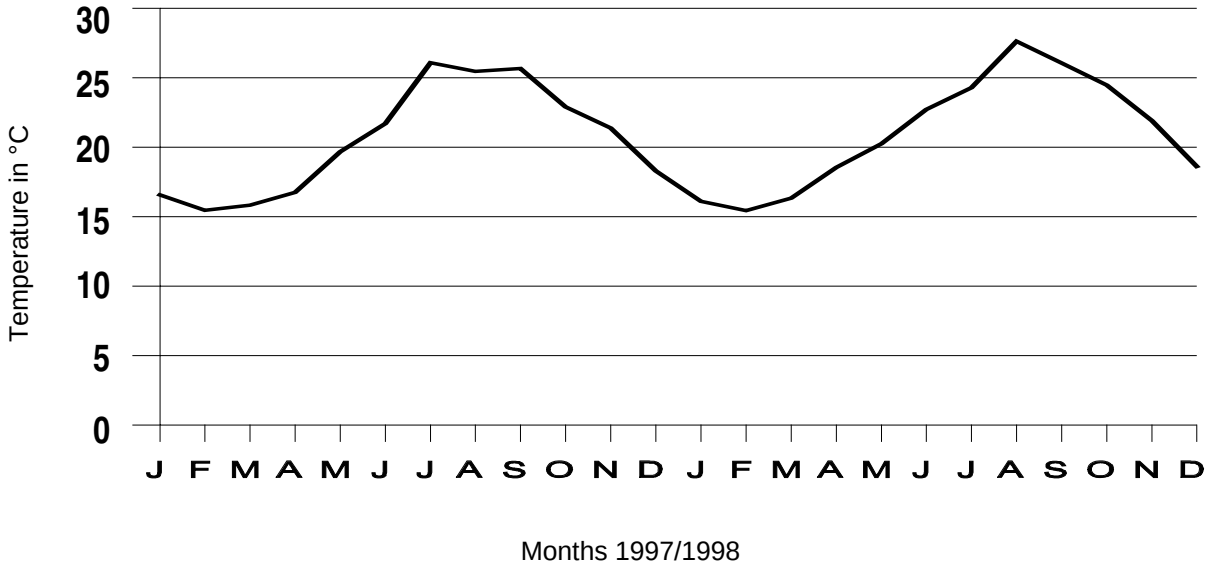


Fig. 2. Average seawater temperature (time 07:30) at the Experimental Marine Aquaculture Station Meneou.

## Spawning manipulations

One year old fish reared from egg at the Meneou Station were found to have developed gonads and it is assumed that they can spawn at this age. They were hatched in June 1995 and sampled in June 1966. The females had preovulated oocytes present in the ovary. The gonadosomatic index (GSI) of the males ranged from 7.09 to 13.25 and of the females 2.63 to 8.68, while the average GSI was 10.31 and 6.06 respectively. According to data by Popper and Gundermann (1975) who examined and sampled fish from the Gulf of Aqaba and the Mediterranean, *S. rivulatus* with such gonadosomatic index are ripe.

In order to plan and coordinate the production of this species on a commercial scale *S. rivulatus* broodstock should be managed in such a way so that it will give eggs all year round (Table 1). The off season spawning of *S. rivulatus* was attempted at the Meneou Station in the winter of 1998. In the beginning of January twelve two year old fish of an average weight of 250 g were moved from the outdoor shaded tank which had ambient sea water temperature 15°C, 10 hours light-14 hours dark, to an indoor round 3 $m^3$ fiber glass tank, where environmental manipulation could be applied. With the objective to induce the fish to spawn in March, the water temperature was raised gradually to 24°C and the photoperiod to 14 hours light and 10 hours dark daily. The fish kept feeding actively on dry commercial diets and fresh vegetables. The salinity was maintained at ambient levels (39‰) and the water quality was monitored regularly. The light intensity on the water surface ranged from 1000 to 2000 lux. By the end of February some fish started hydrating and on the 6th March 1998, they spawned. The broodstock spawned for the second time on the 15th April 1998, for the third time on the 15th May 1998 and for the fourth time on the 18th June 1998. Always two to three days before spawning the broodstock stopped feeding or were feeding very little.

Exactly the same environmental manipulation with different *S. rivulatus* broodstock was tried out in January 1999 with the same successful results as in 1998 (Table 1). The first spawning was received on February 28th, the second on April 1st, the third on April 29th. Various methods for the removal of either the eggs or the spawners were tried. The spawners, purposely placed in a small cage, are removed after the eggs hatch and are transferred to a new spawning tank.

The average weight of the selected broodstock was 192 g. The average gonadosomatic index of a

sample of fish from the same group from where the broodstock came was 1.08 for females, (the range was 0.3 to 3.1) and 1.9 for males (the range was 0.6-3.1).

Table 1. Environmental conditions and off season spawning pattern of *Siganus rivulatus*

| Starting dates | Photoperiod light-dark hours | Light intensity (lux) | Temperature at spawning (°C) | Salinity (‰) | Spawning dates | Full moon dates |
|---|---|---|---|---|---|---|
| 11/1/98 | 14-10 | 1000-2000 | 24 | 39 | 6/3/1998 | 13/3/1998 |
| | 14-10 | 1000-2000 | 24 | 39 | 15/4/1998 | 15/4/1998 |
| | 14-10 | 1000-2000 | 24 | 39 | 15/5/1998 | 11/5/1998 |
| | 14-10 | 1000-2000 | 24 | 39 | 18/6/1998 | 9/6/1998 |
| 8/1/99 | 14-10 | 1000-2000 | 24 | 39 | 28/2/1999 | 2/3/1999 |
| | 14-10 | 1000-2000 | 24 | 39 | 1/4/1999 | 1/4/1999 |
| | 14-10 | 1000-2000 | 24 | 39 | 29/4/1999 | 28/4/1999 |

Sex distinction is possible in mature spawners only. By pressing gently the abdomen, mature males will give sperm.

## Eggs and their incubation

Eggs are always found in the morning. At 07:00, when found, they are attached to the sides and the bottom of the spawning tank and usually they are at the 8 cell division stage. It is estimated that about 2.5-3.5 hours are needed to reach this incubation stage at 24°C, so it is assumed that spawning takes place at about 04:00-05:00 hours. The egg diameter is 630 µm, and they hatch in 34-26 hours at 24-26°C. Light aeration is applied in the tank.

It has not been possible to estimate the egg fertilization and hatchability rate, because of their demersal nature.

## Larval rearing

Larval length at hatching is 1.80 mm. They have a relatively large yolk sac and float passively. After day 2 as the yolk sac decreases they become more mobile. Larvae on day 2 were moved from the spawning/hatching tank to rearing tanks at various densities and rearing conditions. The mouth is formed between day 2-3, so feeding was started right before this stage, at the beginning of day 2. Eight larval rearing trials in total were made during 1997 and 1998, four in 1997 with larvae from natural spawning and four in 1998 with larvae from off season spawning (Table 2). The green water technique was employed in most trials. A mixture of phytoplankton species was tried out consisting of *Chlorella* sp., *Tetraselmis suecica, Nanochloris* sp., *Dunaliella* sp. and *Chlorococcum* sp.

In 1997 the first natural spawning was received on 21/6/97 and the first larval rearing trial was initiated. One day old larvae were moved from the spawning/hatching tank to a 10 $m^3$ rearing tank, at a density of 10 larvae/L. The tank was prepared applying a form of the mesocosm technology (Divanach and Kentouri, 1989). The tank was inoculated with *Chlorella, Nanochloris, Tetraselmi*s and *Dunaliella* and when the larvae were 2 days old, with a strain of small rotifers (*Brachionus plicatilis)* reared on phytoplankton, their size ranging from 120-300 µm. On day 2 the rotifer density was 4/ml and the density of the algae 0.5 x $10^6$ cells/ml. No water exchange was carried out during the first 5 days. Light aeration was applied. Mass mortalities occurred on day 4-5. The larvae failed to start feeding. About 70 fry were produced from this trial. Dry food was given from day 18 and on day 25 the larvae were weaned. The second, third and fourth trials in the summer of 1997 gave similar results. The same culture system was applied, only higher densities of rotifers and algae were applied while super small (SS) strain rotifers (90-150 µm) were used, in the fourth trial. The initial larval density was 15/L. The temperature was 26-28°C and slight water exchange was applied (1 L/min). The survival was very limited in all trials, mass mortality occurred on day 4-5. A locally isolated phytoplankton species

*Chlorococum* sp. was used in the larval rearing tanks and also separately on it's own using small larval tank. The size of this phytoplankton is 16-18 µm. It was found in the stomach of several larvae which were sampled.

Table 2. *S. rivulatus* larval feeding regime and results

| Date | Larval density | Initial feeding and density[†] | Survival | Remarks |
|---|---|---|---|---|
| June 1997 | 10/L | Mixed algae 0.5 x $10^6$ C+N+T+D cells/ml<br>Rotifers 4/ml | 70 fry | Mesocosm Technology<br>Mortalities on day 4-5 |
| July 1997 | 15/L | Mixed algae 1.0 x $10^6$ C+N+T+D cells/ml<br>Rotifers 10/ml | 30 fry | Mesocosm Technology<br>Mortalities on day 4-5 |
| August 1997 | 15/L | Mixed algae 1.0 x $10^6$ C+N+T+D+Ch cells/ml<br>Rotifers 10/ml | 7 fry | Mortalities on day 4-5 |
| Sept. 1997 | 15/L | Mixed algae 1.0 x $10^6$ C+N+T cells/ml<br>SS rotifers 5/ml | 3 fry | Mortalities on day 4-5 |
| March 1998 | 10/L | Mixed algae C+N+T<br>SS rotifers 5/ml | 2 fry | Intensive culture system |
| April 1998 | 10/L | Mixed algae C+N+T<br>SS rotifers 5/ml | 3 fry | Intensive culture system |
| May, June 1998 | 5, 10, 15, 20/L | Mixed algae C+N+T<br>SS rotifers 10/ml | – | Intensive culture system |
| March 1999 | 10/L | Mixed algae C+N+T<br>SS rotifers 5/ml | – | Intensive culture system |
| April 1999 | 15/L | Mixed algae C+N+T<br>SS rotifers 5/ml | 100 fry | Intensive culture system |

[†]C = *Chlorella*; N = *Nanochloris*; T = *Tetraselmis*; D = *Dunaliella*; Ch = *Chlorococcum*.

The larval rearing trials in 1998 were started in March when the first off season spawning was made possible, employing similar biotechnology as used for the intensive production of *S. aurata* fry. Larval density was 10/L, using 3 $m^3$ cylindroconical tanks, with an open water circulation, 1 L/min at the beginning, which was later increased. For the third and fourth trial four 0.5 $m^3$ cylindroconical tanks were employed using larval densities from 5-20/L. Enriched SS strain rotifers (Fuji and Thai strain) were added 2 times a day and about 30 L of phytoplankton was added to the tank twice daily. The physicochemical parameters were recorded twice a day during the culture and were: DO 7-8.00 mg/l, salinity 39‰, pH 7, temperature 24±0.5°C and the light intensity on the water surface about 1000 lux. The SS rotifers were cultured on *Chlorella*, at a temperature of 35°C and salinity 20‰, to ensure the smallest possible rotifer size. The mass mortalities which were observed in previous trials occurred again on day 4-5.

A similar intensive culture system was employed in the 1999 larval rearing trials (Table 2). A the second trial, in April 100 fry were produced. It was observed, from samplings, that on day 4 several larvae had algae in their stomach, but not rotifers.

## Fry growth

The growth rate of this species at the juvenile stage is remarkable. Fry produced from eggs, spawned on 21 June, 1997, were weaned and had an average length of 2.5 cm at the age of 32 days.

At this age they started swimming in schools searching for food at the bottom and the sides of the tank. By the 20th August, 1997 age 60 days, they reached the average weight of 6.5 g and average length of 7.6 cm, while at the end of 1997, age 120 days old, the average weight was 68.9 g and the average length 16.0 cm. The growth slows down considerably with the drop of the temperature in the winter.

## Discussion and conclusion

The control of reproduction is an important step forward in the effort to culture *S. rivulatus* on a commercial scale. Spawning of *S. rivulatus* was managed spontaneously during the natural spawning season in the summer (June-September) of 1997 and also spontaneously, but off season, from March to June 1998, using environmental manipulation. The protocol developed for the off season spawning was repeatedly tested with successful results.

The larval rearing of *S. rivulatus*, however, requires further study and research work centered on the production of the right size prey for the initial feeding. The small size larva has a mouth opening of about 100 µm. Therefore it requires a smaller size prey than SS rotifers (90-150 µm). Rotifers are too big for them to ingest. A smaller size food, which is digestible is perhaps needed before the larvae are given rotifers. It is assumed that the slightly better results received when applying the mesocosm technology, could be due to the fact that some other planktonic organism is available in the larval tank on which the larvae can prey. From all the trials together it can be concluded that the size of the prey is the limiting factor and that phytoplankton alone can not support larval survival. Such an assumption is supported by the fact that *Chlorococcum* and other algae were found in the stomach of 4 day old larvae, however, the survival was very low.

The fact that *Siganids* are herbivorous fish makes their culture most interesting. Although their nutritional requirements were not yet studied, low protein diets (rabbit food) and terrestrial fresh vegetables, mainly clover (*Medicago sativa*) were acceptable as food. This is a significant advantage from the cost of production point of view and also from the energy point to of view, especially if our concern is to promote a sustainable development of the aquaculture industry.

*S. rivulatus* does not grow big in size, only up to 350 g and one may think that this could be regarded as a disadvantage for its culture. However, in the countries where it exists it is marketed successfully even at small sizes. In Cyprus marketable size ranges between 200-250 g. A problem or disadvantage, that its culture may present is due to the fact that the first rays of its dorsal fin are poisonous which could make the handling (grading, harvesting) difficult.

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