Culture of Seriola dumerilii

García A., Díaz M.V.

Marine aquaculture finfish species diversification

Zaragoza : CIHEAM
Cahiers Options Méditerranéennes; n. 16

1995
pages 103-114

Culture of *Seriola dumerilii*

A. GARCIA
CENTRO OCEANOGRAFICO DE MURCIA
INSTITUTO ESPAÑOL DE OCEANOGRAFIA (IEO)
CTRA. DE LA AZOHIA S/N
30860 MAZARRON
MURCIA
SPAIN

M.V. DIAZ
DEPARTAMENTO DE BIOLOGIA CELULAR
FACULTAD DE BIOLOGIA
UNIVERSIDAD DE MURCIA
CAMPUS DE ESPINARDO
CTRA. DE MADRID S/N
30100 MURCIA
SPAIN

SUMMARY - *Seriola dumerilii* (Risso 1810) is a marine fish specie wich is becoming important in aquaculture. Its fast growth rate (reaching 1 kg in the first year), good performance in captivity (acceptance of artificial feeding regimen and low mortality) and high commercial value (10-20 ECU/kg) make it a suitable specie for intensive farming.

Bottle-necks in their culture are reproduction, feeding and pathology. At present, reproduction in captivity have not been successful in the mediterranean countries. Only a few attemps of artificial fertilization with wild broodstock have produced up to 10 days old larvae. On the contrary, japanese scientists have been successful with the reproduction and larval rearing of *S. dumerilii* (called "Kampachi") since 1979 but with most success since 1987. At present, the production of *S. dumerilii* is mostly based on raising fingerlings captured from the wild. On-growing is generally made in the mediterranean countries (Spain, Italy) as in Japan on net cages, by using fresh or frozen raw fish as food. More recently, moist pellets are replacing raw fish. *S. dumerilii* dislike dry pellets, but a newly developed extruded pellet, a so called "soft-dry pellet", has a high acceptability and palatibility for the japanese yellowtail (*Seriola quinqueradiata)* and potentially for the mediterranean specie. Actually, the current diseases are not so important, except for the 0^+ age class fish where mass mortality sometimes happen dued to a *Chlamydia*-like epitheliocystis organisms and sanguinicolidae blood flukes.

The actual knowledge and techniques about reproduction, larval rearing and on-growing of *S. dumerilii* in the mediterranean countries and in Japan, as well as the main problems and prospects in their culture are rewieved in this presentation.

Key words: *Seriola*, yellowtail, amberjack, reproduction, larval rearing, feeding, pathology

RESUME - *Seriola dumerilii (Risso 1810) est un poisson marin d'une importance croissante pour l'aquaculture. Sa croissance rapide (1 kg la première anne) sa bonne adaptation a la captivité (acceptant une alimentation artificielle et faible mortalité) et sa haute valeur commerciale (10-20 ECUS/kg) en fon une espèce cible pour l'élevage intensif.*

Les facteurs limitant son élevage sont la reproduction, l'alimentation et la pathologie. En méditerranée et jusqu'à ce jour la reproduction en captivité n'a pas été obtenue. On n'a pu obtenir que quelques larves de 10 jours, au travers d'essais de fécondation artificielle sur des reproducteurs sauvages. Par contre, au Japon, la reproduction et l'élevage larvaire de S. dumerilii (appelée "Kampachi") sont obtenus avec succès depuis 1979 et de façon plus intense depuis 1987. En Méditerranée (Espagne et Italie) la production de S. dumerilii se base actuellement sur le groissement d'alevins capturés en mer. Il se réalise comme au Japon, en cage fondamentalment, alimenté avec du poisson frais ou congelé à basse valeur commerciale. Récemment on substitue le poisson par des composés semi-humides. S. dumerilii n'aime pas les composés sous forme de granulés secs, mais un type de granulés extrués recemment developpé, appelée "soft-dry pellet", a montré haute acceptation et palabilité chez la sériole japonaise (Seriola quinqueradiata) et est potentiellement utilisable chez l'espèce méditerranéenne. Les maladies existantes ne sont pas actuellement très importantes, sauf pour les poisson de la classe d'âge 0^+ où on atteint parfois des mortalités massives, dues à des organismes du type Clamydia causant l'épithélyocystis et à des trématodes sanguicoloïdés.

Dans cette présentation on révise la connaisance actuelle et les techniques de reproduction, élevage larvaire et le groissement de S. dumerilii autant dans les pays méditerranéens qu'au Japon, ainsi que les principaux problèmes et perspectives de futur de son élevage.

Mots-clés: *Seriola*, yellowtail, amberjack, reproduction, élevage larvaire, alimentation, pathologie.

GENERAL CHARACTERISTICS

Seriola dumerilii (Risso 1810) is a marine teleost fish (*Perciformes, Carangidae*). Its common names in the different languages and countries are: greater or purplish amberjack or mediterranean yellowtail (english); liche or sériole couronnée (french); lecha, serviola, medregal or pez limón (spanish); ricciola (italian); mayático (greek); sarikuyruk baligi (turquish); orfan (yugoslavian); mineri (Cyprus); accrole (Malt); irghal (Morocco); guerriona (Tunis); tsola (Libya); insh (Egypt); intras (Syria) and seriola (Israel) (Fischer, 1973).

Its main morphological characteristics are body elongated, fusiform and slightly compressed laterally, with small scales (cycloids). Colour is yellow-green in juveniles and in adults, blue or olivaceous dorsally and silvery to white in sides and belly. It has a dark nucal bar from the eye to the anterior part of the dorsal fin base. Juveniles have 5 dark lateral body bands and a sixth bar at the end of caudal fin. Maximum report size is 180 cm in total lenght and 80.6 kg in body weight, but commonly are 110

cm and 25-40 kg (Fischer, 1973; Smith-Vaniz, 1986; Fischer *et al.*, 1987).

Concerning to their habitat (Smith-Vaniz, 1986), is both epibenthic and epipelagic. It can be found often near reefs or at deep offshore holes or drops off, at 18-72 m deep up to 360 m. They are usually forming small to moderate schools but occasionally are solitary. Small juveniles (less than 100 g) are normally associates with flotsan in oceanic or offshore neritic waters. Their natural food consist primary on fishes (mackerel, anchovy, sardine) but also invertebrates (squids).

Distribution of *S.dumerilii* (Smith-Vaniz, 1986) is from Mediterranean to the Gulf of Biscay and rarely in the British Coast. Also it can be found from Nova Scottia (Canada) to Brazil, South Africa, Arabian Gulf, Australia, Japan and Hawaian Island.

This fish specie is caught commercially with trawls, purse seines, traps (set nets) and/or line gears. No good official data of fisheries catches are available. Estimated catches in the mediterranean are: 100-200 Tm (Spain); over 100 Tm (Italy and Israel); 25-100 Tm (Syria, Yugoslavia, Cyprus).

REPRODUCTION

In *S.dumerilii* both sexes are separated. Undifferentiated gonads persist until the 11th month of life. Maturity occurs at three years old but functional breeders are when they are 4 years old (males) and 5 years old (females) (Micale *et al.*, 1993).

S. dumerilii is a multiple spawning fish. The type of the ovary is group synchronous, in which at least two size groups of oocytes are present at some time (Grau, 1992). The spawning season is protracted and last from late spring to early summer (from May to July) (Lazzari and Barbera, 1988, 1989a; Grau, 1992).

Gonads occupies 2/3 of the body cavity lenght when its fully ripe. Gonadosomatic index varies throughout the years between 0.51-15.56 in females and 0.05-8.23 in males and total fecundity is 600 eggs/g in young mature females (around 15 kg) and 130 egg/g in older females (over 30 kg) (Grau, 1992).

In captivity, males reach a certain degree of maturity, releasing a small amount of sperm, but females have a less mature gonads arrested at the beggining of vitellogenesis (secondary yolk stage) (unpublished data).

Over 15 years, experiments to get spawning in captivity have been carried out in the mediterranean countries. Wild mature animals kept in captivity at the spawning season have been occassionally successfully induced to spawning. Also, artificial fertilization of eegs with sperm, both from wild broodstock, have allowed to get some larvae (Sanzo, 1933; Di Bitteto and Lazzari, 1991; Lazzari, 1991; Grau, 1992). In our laboratory, *S. dumerilii* reared in captivity for 6 years (from 100 g) and hormonal induced, have spawned a small amount of eggs but not fertilized (unpublished data).

On the contrary, japanese scientists have been successful with the reproduction and larval rearing of *S.dumerilii* (called "Kampachi") since 1979 and with more success

since 1987 (Totsui *et al.*, 1979; Tukashima *et al.*, 1987; Masuma, 1988, 1989; Masuma *et al.*, 1990; Tachihara *et al.*, 1993). They normally catch wild mature fish in a set net during the spawning season and stock it in cages. Depending on the degree of maturity in females, check it by cannulating and seizeing the oocytes, are induced with an injection of Human Chorionic Gonadotropin (HCG) or a derivative (Synahorin) and/or Luteinising Hormone-Releasing Hormone analogue (LHRHa) injection or pellet implantation. Doses are 700-1000 UI of HCG and 10-50 µg/kg LHRHa for injection or 100 µg/kg for pellets. Then, the breeders are transfered to a concrete tank on ground (90 m^2) to spawn. Spawning occurs 37-52 hours after induction, depending of water temperature (Totsui *et al.*, 1979; Tachihara *et al.*, 1993).

Eggs of *S.dumerilii* are pelagic, spherical in shape and 1.0-1.2 mm in diameter with a single oil globule of 0.2-0.3 mm (Sanzo, 1933; Masuma, 1988, 1989; Masuma *et al.*, 1990; Di Bitetto and Lazzari, 1991; Lazzari 1991; Tachihara *et al.*, 1993). Yolk is roughly segmented and the perivitelline space is narrow (Masuma *et al.*, 1993).

First division occurs over 30-40 minutes after fertilization (depending of seawater temperature). Next divisions occurs after a 45-50 minutes period. Hatching take place 35 hours (23-27°C) or 48 hours (19.8°C) after fertilization (Masuma *et al.*, 1990; Lazzari, 1991; Tachihara *et al.*, 1993). Masuma (1989) obtained a hatching rate up to 60% with hormonal induced breeders.

LARVAL REARING

In the mediterranean countries, only larvae up to 10 days have been obtained by artificial insemination (Grau 1992). In Japan, *S. dumerilii* have been reared from hatching to the juvenile stage (Masuma *et al.*, 1990; Tachihara *et al.*, 1993).

Newly hatched larvae are 2.7-3.1 mm in notochord lenght (Tachihara *et al.*, 1993). Di Bitteto and Lazzarri (1991) reported early larvae of 1.2 mm length. Tachihara *et al.* (1993) stated the morphological development of the larvae at 23-27°C in different stages (Table 1).

Table 1. Days old and standard length according to the stage of morphological development of *Seriola dumerilii* larvae (adapted from Tachihara *et al.*, 1993)

Stage	Days	Standard length (mm)
Pre- larvae	1 - 3	2.7 - 3.9
Post-larvae	4	3.6 - 4.0
	14 - 21	6 - 11
Juvenile	23 - 30	11 - 20
	35 - 45	30 - 50
Young fish	over 100	100 - 150

Larvae are usually reared in 6000 l tank. From day 4 to day 35 are reared in a 25-30 m^2 tank and after that in a 2 x 2 x 2 net cage with a mesh size of 5-10 mm.

The feeding schedule used in *S. dumerilii* is the same as in *S. quinqueradiata* (Japan Sea-Farming Association, pers. comm.) (Table 2).

Table 2. Feeding schedule of *Seriola dumerilii* used in Japan (JASFA, pers. comm.)

Type of food	Larvae lenght (mm)	Days after hatching	Amount of feeding
Rotifer	3.5 - 10	3 - 10	10/ml
Artemia nauplii	4.5 - 15	8 - 25	0.2 - 0.5/ml
Pellets:			
200 - 400 µ	8 - 12	10 - 25	small amount
400 - 700 µ	10 - 20	25 - 30	small amount
700 - 1000 µ	15 - 30	30 - 40	10 - 20 %[1]
> 1000 µ	over 25	> 40	20 %[1]

[1]Percentage of body weight.

ON-GROWING

In the mediterranean countries (Spain, Italy) as in Japan, production of *S. dumerilii* is mainly based on raising fingerling captured form the wild at the end of the summer. In Japan, juveniles (called "Mojako") of 2-10 g are caught under drifting sargassum seaweed with a circular net. In the mediterranean, young fish (25-100 g) are captured from the end of August to the beginning of October by using floating object made it with leaves and branchs called "ramos or catcés" wich atach them (Grau, 1992; Greco *et al.*, 1991) or using a kind of nases (Di Bitteto and Lazzari, 1991).

The japanese culture technique for *S. dumerilii* is the same as for *S. quinqueradiata* (Harada, 1965; Cimmino, 1973; Muller-Feuga, 1973; Giovanardi, 1981; Peña, 1981; Nakada y Murai, 1991; Grau, 1992, Ikenoue and Kakufu, 1992). Mojako are firstly deparasited by immersion in freshwater. Then, they are clasified in some size groups and put it on a 2 x 2 x 2 m net cage. Stocking rate is 1600 - 2000 fish/m^3. At 50 g (4-6 weeks after) fish are grading again in order to prevent cannibalism. The on-growing net cages are square or circular in shape with a wood, metal or polietilen frame. Juveniles fish are feeding *ad libitum* or at 80% of satiety, 8-10 times a day at the beginning and 2-3 times later on. Young fish are feeding 1-2 times a day, from 30% to 3% of body weight as they are growing. Food is consist primary on low commercial value fish, fresh or frozzen, chopped and mixed with fish oil, fish meal, additives, vitamins and mineral salts forming a moist pellets. Food conversion rate is 7-8.

In the mediterranean, young fish have been reared in concrete tanks (Cavaliere *et al.* 1989; Lazzari and Barbera, 1989b; García, 1993 a,b,c; García *et al.*, 1993; Greco *et al.*, 1993) as in net cages (Giovanardi *et al.*, 1984; Navarro *et al.*, 1987; Grau, 1992; Boix *et al.*, 1993; Porrello *et al.*, 1993). Starting stocking rate used to be 2-3 kg/m^3 reaching up a final rate of 10 kg/m^3 (Grau, 1992). The food is usually raw fish

(*Sardinella aurita*, *Boops boops*, *Trachurus trachurus*, *Spicara maena*) fresh or frozzen, chooped or in bits. Moist pellets have also been used succesfully (Di Bella *et al.*, 1991; García, 1993a,b; García *et al.*, 1993; Greco *et al.*, 1993), specially at low temperatures (under 15°C) when the fish usually stop feeding (García, 1993a,b). Fish feed *ad libitum* have a food conversion rate of 5-7. Growth in weight and lenght, daily growth rate and specific feeding rate according to the age are summarized in Table 3 (García, 1993c and unpublished data).

Table 3. Growth and feeding parameters of *Seriola dumerilii* reared in captivity (modified from García, 1993c and unpublished data).

Age	Weight (g)	Length (cm)	DGR[1,3]	SFR[2,3]
1	1000 - 1100	35-45	0.8 - 1.1	1.7 - 5.6
2	3000 - 3200	60-65	0.3 - 0.4	0.4 - 2.6
3	5000 - 5200	70-75	0.2	*****
4	8000 - 10000	85-95	*****	*****
5	11000 - 13000	95-105	*****	*****

[1]DGR = Daily growth rate
[2]SFR = Specific feeding rate
[3]DGR and SFR varies with the seawater temperature.

PROBLEMS

Reproduction

The production of *S. dumerilii* based on raising wild fingerling it is not a suitable technique from a commercial and ecological point of view, because of the uncertaintes accompayning this practice: variability of annual catches, shortages of fry and potential injury to wild populations. Inducing spawning of wild mature fish it is also not a good strategy becase they are not easilly available in all places and because not always is succesfull, since the management of such a big fishes cause mortality and regression of gonads dued to stress. Artificial insmemination it is difficult too, because females with oocytes at the final maturation stage rarely occurs (Manganaro *et al.*, 1993). Moreover, stripping in this specie is quite difficult because they have a hard belly.

For this reasons, it is neccessary to gain a better knowledge about the endocrine regulation of reproduction in *S. dumerilii* in order to be able to induce breeding in captivity. In this sense, a research project supported by the European Commision (AIR Programm) is carrying out with the participation of the Spanish Institute of Oceanography (IEO) and the University of Murcia from Spain, and the University of Utrecht from The Netherland. The aim of this project is to compare the changes in the hypothalamic-pituitary-gonadal axis during the reproductive cycle in normal breeding animals from natural environments and in animal reared in captivity. Afterwards, localize and diagnose physiological defects or blockades wich prevent reproduction in

captivity, such as inssuficient synthesis and release of gonadotrophin releasing hormone (GnRH) and/or gonadotrophin hormone (GTH II), a dominating dopaminergic inhibition or too feew or even absence of GnRH receptors in the pituitary. Finally, develop a therapeutic treatment to overcome these defects by using differents hormones (GnRH analogues, with or without dopamine antagonists, gonadotrophin, steroids) and hormonal induction techniques (injections, implants, etc).

Feeding

S. dumerilii feeding is heavily dependent on locally available raw fish. Moreover, feeding raw fish for densely cultured fish frequently results in deterioration of environmental waters in terms of loading nitrogen, phosphorous and oxygen consumming substances due to their loss from the diets, loading to eutrophication and occurrence of various fish diseases (Watanabe *et al.*, 1991). Raw fish also have an unstable nutritive value, poor higienic condition and its preparation and storage require labour and facilities (Shimeno, 1991).

Until 1985, frozen raw fish were used in Japan as the main food for yellowtail culture (Nakada and Murai, 1991; Shimeno, 1991). Practical formulated feeds, such as the Oregon moist pellet, single moist pellet (without fresh fish) and extruded pellet (EP) have been developed and recently used. EP is a soft dry pellet (8-12 moisture) which is well accepted by *Seriola spp.* because is softer than ordinary pellet (Watanabe *et al.*, 1991). This new kind of food is very promising because is cheaper, more nutritive, less polutant and require less labour and facilities than the other ones.

The feeding requirements of *S. dumerilii* are not known so it is needed not only to do research into the kind of food but also into their quality, that means nutritional requirements (proteins, lipids, carbohydrates, vitamins, minerals, energy, etc).

Pathology

Some diseases have been reported on *S. dumerilii* in the mediterranean countries (Crespo *et al.*, 1990, 1992; Genovese *et al.*, 1992; Grau, 1992; Grau and Crespo, 1991; Grau *et al.*, 1993). Recurrent outbreaks of mass mortalities have been occurring in the 0^+ age class since 1988 due to epitheliocystis and sanguinicoliasis (December to March) and pseudotuberculosis (October to January). Fish losses also occur in the 1^+ age class resulting in a final mortality of 3% related only to sanguinicoliasis. Epitheliocystis is a chronic but not patogenic infection in fish over one year old. Icthyophoniasis, vibriosis, trichodiniasis and equinostomatidiasis have also been reported in *S. dumerilii* (Genovese *et al.*, 1992; Grau, 1992).

In Japan, main diseases reported in *S. dumerilii* are epitheliocystis and parasites infection like microsporidiasis, *Nocardia kampachi* and *Benedemia seriolae* (Japan Sea-Farming Association, pers. comm.). In *S. quinqueradiata* the most important diseases are Streptococcus, *Pasteurella piscida* (pseudotuberculosis), vibriosis, *Nocardia* and *Flexibacter* (Kusuda, 1990; Nakada and Murai, 1991; Egusa, 1992) and a specific viral disease called yellowtail ascite virus (YAV) (Ishiki *et al.*, 1989). These

diseases will probably affect to *S. dumerilii* in the future as the production will be increasing.

The use of artificial feeding plays an important role in improving the survival rate and recovery from diseases (Taniguchi, 1982; Genovese *et al.*, 1992). In recent experiments on *S. dumerilii*, Gonzalez *et al.* (1995) observed that no relationship between feeding regime and intensity of disease could be established for epitheliocystis but sanguinicoliasis did not spread out in the 1^+ age class fish fed with moist pellets.

PROSPECTS

S. dumerilii is a good candidate specie for the diversification of aquaculture fish products because of its high growth rate and good performance in captivity (acceptance of food, low mortality). There is also a good local market in the mediterranean region as in Japan. Sales prices reach 10-20 ECUS/kg in the mediterranean and 30 ECUS/kg in Japan. One of the most interesting thing is that this fish can be sell it at every size (in whole or in slices).

S. dumerilii have already been commercially farmed in Spain and in Italy and when the problems of fingerling supply and some diseases will be solved and the feeding will be improved, their culture will be probably extended in the mediterranean countries.

Despite some differences, the mediterranean yellowtail has both morphological and farming affinities with the japanese yellowtail (*S. quinqueradiata*). This is one of the most popular fish in Japan and its cultured production has been the highest of the cultured marine finfish species for more than 20 years. Tonnage and value of its production reach 150.000 tonnes and 1 billion dollars each year (Nakada and Murai, 1991; Shimeno, 1991). Actually in Japan, the production of yellowtail is diversificating in other yellowtail species (*S. dumerilii* and *S. lalandi*) because of a reduction in the sale price of *S. quinqueradiata*. So, *S. dumerilii* could become in a new valuable specie not only in the mediterranean countries but also in Japan for the next future.

REFERENCES

Boix, J., Fernández, J.V. and Macia, G. (1993). El cultivo de seriola (*Seriola dumerilii*, Risso 1810) en jaula flotante en el término de Les Cases d'Alcanar (Tarragona). *Actas IV Congreso Nac. Acuicult.*: 133-136.

Cavaliere, A., Crisafi, E., Faranda, F., Greco, S., Lo Paro, G., Manganaro, A. and Mazzola, A. (1989). Collection of fingerling and rearing of *Seriola dumerilii* in tanks. In *Aquaculture - A Biotechnology in Progress*. N. de Pauw, Jaspers, E., Ackefors, H. and Wilkins, N. (Eds). European Aquaculture Society, Bredene, Belgium. pp. 119-123.

Cimmino, C. (1973). L'allevamento della seriola (*Seriola quinqueradiata*, T. & S.) in

Giappone quale metodo di coltura marina introducible in Italia. *Boll. Piscicoltura e Idrobiologia.* Vol. XXVIII Fasc. 2: 245-315.

Crespo, S., Grau, A. and Padros, F. (1990). Epitheliocystis disease in the cultured amberjack, *Seriola dumerilii* Risso (*Carangidae*). *Aquaculture* 90: 197-207.

Crespo, S., Grau, A. and Padros, F. (1992). Sanguinicoliasis in the cultured amberjack, *Seriola dumerilii* Risso, from the Spanish Mediterranean area. *Bull. Eur. Ass. Fish. Pathol.* 12(5): 157-159.

Di Bella, G., Genovese, L. and Salvo, F. (1991). Effect of different diets on muscle and liver fatty acids composition in *Seriola dumerilii* intensevely reared. In *Aquaculture and the Environment. European Aquaculture Society Special Publication* No. 14: 90-91.

Di Bitteto, M. and Lazzari, A. (1991). *Biologia, experienze di allevamento e studi sulla riproduzione della ricciola.* Report prepared for the Ente per le Nuove tecnologie, l'Energie e l'Ambiente (ENEA). pp. 1-88.

Egusa, S. (1992). *Infectious disease of fish.* A.A. Balkema. Rotterdam.

Fischer, W. (1973). *Fiches FAO d'Identification des espèces pour les besoins de la pêche. Meditérranée et mer Noire, Zone de Pêche 37. Vol. II: Vertébrés.* FAO, Rome.

Fischer, W., Schneider, M. and Bauchot, M.L. (Eds.). (1987). *Fiches FAO d'Identification des espèces pour les besoins de la pêche. Meditérranée et mer Noire, Zone de Pêche 37. Vol. II: Vertébrés. Révision 1.* FAO, Rome.

García, A. (1993a). Crecimiento y comportamiento alimentario de alevines de Seriola mediterránea (*Seriola dumerilii*, Risso 1810) alimentados con un pienso semi-húmedo. In *From Discovery to Commercialisation. European Aquaculture Society Special Publication* No. 19: 373.

García, A. (1993b). Primeras experiencias de crecimiento de juveniles de seriola mediterránea (*Seriola dumerilii*, Risso 1810) alimentados con una dieta semihúmeda. *Bol. Inst. Esp. Oceanogr.* 9(2): 347-360.

García, A. (1993c). Crecimiento y comportamiento alimentario de seriola mediterránea, *Seriola dumerilii*, en tanques. *Actas IV Congreso Nac. Acuicult.*: 137-142.

García, B., Moreno, J. and Rosique M.J. (1993). Rate of feeding, growth and gross efficiency in juveniles of yellowtail, *Seriola dumerilii.* In *Production, Environment and Quality. European Aquaculture Society Special Publication* No. 18: 255-260.

Genovese, L., Di Bella, G. Patti, F., Micale, V. and Greco, S. (1992). Isolamento di *Vibrio anguillarum* in *Seriola dumerilii* (Risso 1810) in allevamento intensivo. *Oebalia* Vol. XVII (2 suppl.): 123-128.

Giovanardi, O. (1981). Aspetti della maricoltura in Giappone con particolare riferimento alla piscicoltura marina. Parte III: Biologia ed allevamento della *Seriola quinqueradiata* e de *Pagrus major*. *Riv. It. Piscic. Ittiop.* A - XVI No. 2: 43-54; No. 3: 70-76.

Giovanardi, O., Mattioli, G., Piccinetti, C. and Smabucci, G. (1984). Prime esperienze sull'allevamento della Ricciola (*Seriola dumerilii*, Risso 1810) in Italia. *Riv. It. Piscic. Ittiop.* A-XIX No 4: 123-130.

Grau, A. (1992). *Aspectos histológicos, ciclo reproductor y principales procesos patológicos de Seriola dumerilii, Risso 1810 (Carangidae)*. PhD Thesis, Facultat de Veterinaria, Universitat Autonoma, Barcelona.

Grau, A. and Crespo, S. 1991. Epitheliocystis in the wild and cultured amberjack *Seriola dumerilii* Risso: ultraestructural observations. *Aquaculture,* 95: 1-6.

Grau, A., González, G., Pastor, E., Layous, E. and Crespo, S. (1993). Histopathological observations of wild amberjack *Seriola dumerilii* from the Spanish Mediterranean area. In *From Discovery to Commercialisation. European Aquaculture Society Special Publication* No. 19: 379.

Greco, S., Caridi, D., Cammaroto, S. and Genovese, L. (1993). Preliminary studies on artificial feeding of amberjack fingerlings. In *Production, Environment and Quality. European Aquaculture Society Special Publication* No. 18: 247-254.

González, G., García, A., Jover, M. and Crespo, S. (1995). Influence of artificial food on 1+ amberjack (*Seriola dumerilii*, Risso) sanguinicoliasis and epitheliocystis. *Bull. Eur. Ass. Fish Pathol.*, 15(1): 14-16.

Harada, T. (1965). Studies on propagation of yellowtail (*Seriola quinqueradiata*). (in japanese with a summary in english. *Memoirs Fac. Agric. Kinki Univ.* 3: 1-291.

Ikenoue, H. and Kakufu, T (Eds.). (1992). Yellowtail (*Seriola quinqueradiata*). In *Modern methods of Aquaculture in Japan. Development in Aquaculture and Fisheries Science,* 24. Elsevier, Amsterdam. pp. 131-143.

Ishiki, T., Kawai, K. and Kusuda, R. (1989). Incidences of yellowtail ascites virus (YAV) in wild yellowtail fingerlings (in japanese with a summary in english). *Nippon Suisan Gakaishi* 55(4): 633-677.

Kusuda, R. (1990). History and current topics of diseases in cultured yellowtail, *Seriola quinqueradiata* (in japanese). *Suisanzoshoku* H-2, 38(3): 312-313.

Lazzari, A. (1991). Some notes to the aquaculture to the aquaculture development of the new mediterranean species: the yellowtail (*Seriola dumerilii*). Case and strategy to come. In *Aquaculture and the Environment. European Aquaculture Society Special Publication* No. 14: 183-184.

Lazzari, A. and Barbera, G. (1988). First data on the fishing of yellowtail (*Seriola*

dumerilii) spawners in the mediterranean basin. *Journal of Aquatic Products*, 2(1): 133-142.

Lazzari, A. and Barbera, G. (1989a). Prime observazione sulla pesca di riproduttori di ricciola, *Seriola dumerilii*, nelle isole pelagie. *Oebalia*, Vol. XV - 2 NS: 645-652.

Lazzari, A. and Barbera, G. (1989b). Farming the mediterranean yellowtail, *Seriola dumerilii* (Risso, 1810) in concrete ponds: results and perspectives. In *Aquaculture - A Biotechnology in Progress*. N. de Pauw, Jaspers, E., Ackefors, H. and Wilkins, N. (Eds). European Aquaculture Society, Bredene, Belgium. pp. 209-213.

Manganaro, A., Barbera, G., Cammaroto, S., Greco, S. (1993). Fishing amberjack, *Seriola dumerilii*, spawners. *Biologia Marina, suppl. al Notiziario S.I.B.M.,* 1: 245-249.

Masuma, S. (1988). Rearing of Kamapachi (in japanese). *Japan Sea-Farming Association Annual Report*, pp. 55-58.

Masuma, S. (1989). Rearing and spawning of Kampachi (in japanese). *Saibai, Japan Sea-Farming Association Quaterly News Magazine*, 49: 21-23.

Masuma, S., Kanematu, M. and K. Teruya, K. (1990). Embryonic and morphological development of larvae and juveniles of the amberjack, *Seriola dumerilii* (in japanese with a summary in english). *Japanese Journal of Ichthyology*, Vol. 37, No. 2: 164-169.

Micale, U., Genovese, L., Greco, S. and Perdichizzi, F. (1993). Aspects of the reproductive biology of the amberjack, *Seriola dumerilii* (Risso, 1810). In *From Discovery to Commercialization. European Aquaculture Society Special Publication* No. 19: 413.

Müller-Feuga, A. (1972). *L'elevage de la seriole au Japon. CNEXO Rapp. Scient. et Technique* No. 15. pp. 1-50.

Nakada, M. and Murai, T. (1991). Yellowtail aquaculture in Japan. In *CRC Handbook of Mariculture. Vol. II: Finfish Aquaculture*. Mc Vey J.P. Ed. CRC Press. Boca Ratón, Florida. pp. 55-72.

Navarro, J.M., Belmonte, A. and Culmarex S.L. (1987). Cultivo de seriola en jaulas flotantes en la Bahía de "El Hornillo" (Murcia SE España). *Cuad. Marisq. Publ. Téc.* 12: 11-16.

Peña, J.B. (1981). La Acuicultura en Japón. III. Técnicas de cultivo de peces. *Inf. Téc. Inst. Inv. Pesq.*, 89: 3-24.

Porrello, S. Andaloro, F., Vivona, P. and Marino, G. (1993). Rearing trial of *Seriola dumerilii* in a floating cage. In *Production, Environment and Quality. European Aquaculture Society Special Publication* No. 18: 299-307.

Sanzo, L. (1933). Uova, larve e stadi giovanili di *Seriola dumerilii* Risso. *Memoria Regio Comitato Talassografico Italiano* CCV - II: 1-14.

Shimeno, S. (1991). Yellowtail, *Seriola quinqueradiata*. In *Handbook of nutrient requirement of finfish*. Wilson, R.P. Ed. CRC Press, Boca Raton, Florida. pp. 181-191.

Smith-Vaniz, W.F. (1986). Carangidae. In *Fishes of the North-eastern Atlantic and the Mediterranean*. Vol. II. UNESCO. pp. 815-844.

Tachihara, K., Ebisu, R. and Tukashima, Y. (1993). Spawning, eggs, larvae and juveniles of the purplish amberjack (*Seriola dumerilii* (in japanese with a summary in english). *Nippon Suisan Gakkaishi*, 59(9): 1479-1488.

Taniguchi, M. (1982). Influence of food condition on artificial peroral infection of yellowtail streptococciosis. *Nippon Suisan Gakaishi,* 48: 1721-1723.

Totsui, N., Fukumi, T. and Hasegawa, Y. (1979). Stocking, gonadal naturation, artificial spawning and larval rearing of Kampachi (in japanese). *Saibai Giken*, 8(2): 95-103.

Tukashima, Y., Uchida, T., Takaya, M. and Arakawa, T. (1987). Collecting eggs of Kampachi (in japanese). *Annual Report of Nagasaki Prefecture Fisheries Laboratory,* pp. 120-122.

Watanabe, T., Sakamoto, H., Abiru, M. and Yamashita, J. (1991). Development of a new type of dry pellet for yellowtail. *Nippon Suisan Gakaishi*, 57(5): 891-897.