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ISSN 0110-1765

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Fisheries Research Division
Occasional Publication No. 39
1982

Published by the New Zealand Ministry of
Agriculture and Fisheries
Wellington
1982

ISSN 0110-1765

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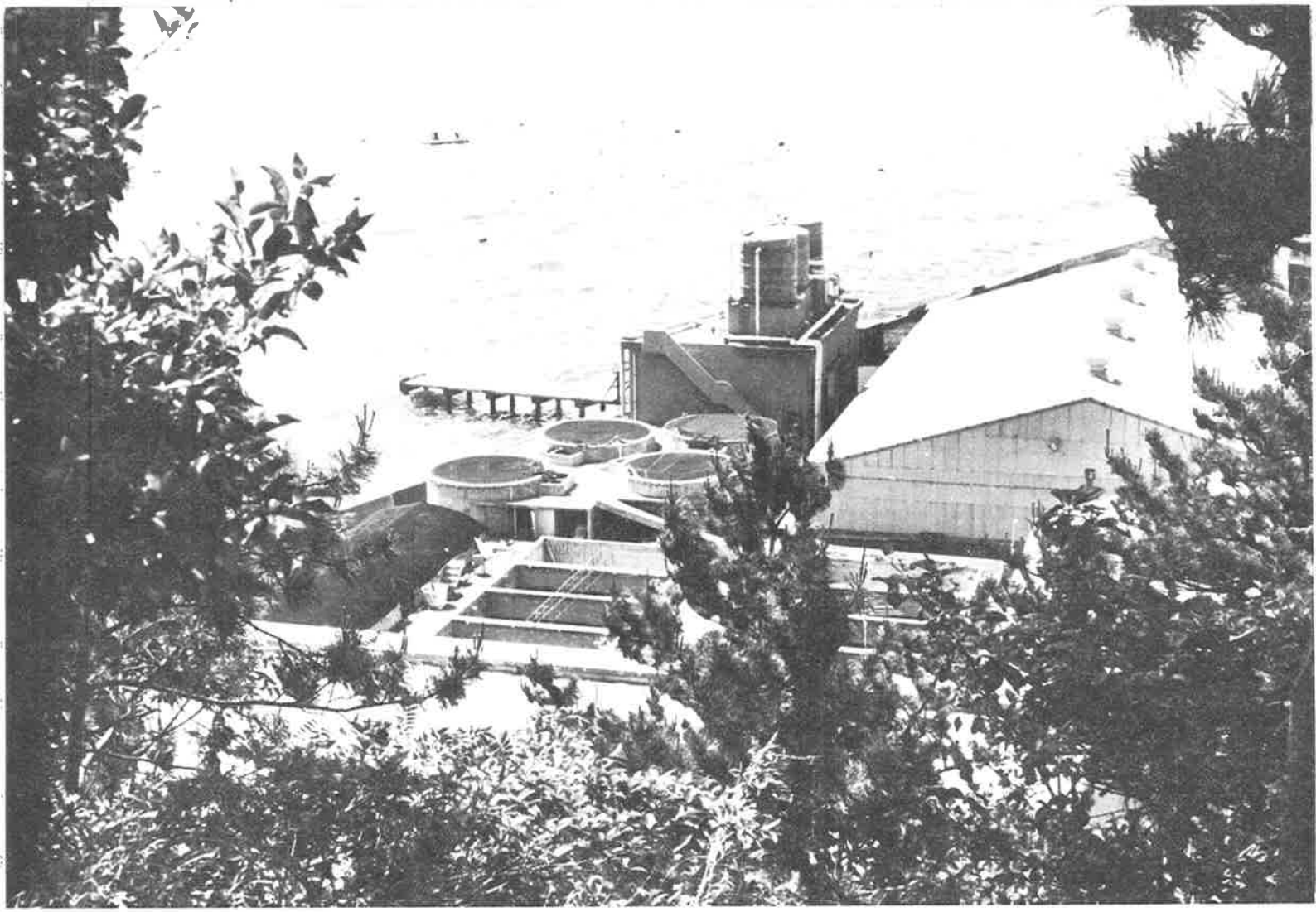


The Shizuoka Prefectural Saibai Gyogyo Centre. The circular ponds are where the red sea bream spawn and the oblong ponds are for algal culture. The 2 towers are filtration plants for incoming sea water. The small boat in the background is being used to feed yellowtail held in submerged cages.

# Introduction

In Japan the red sea bream or madai (*Chrysophrys major**) is king of the marine fish. The species is prized for its firm white flesh and delicate flavour, and it is served at religious ceremonies and on festive occasions. It also features in Japanese tradition and legend.

The annual catch of red sea bream is now about 15 000 t and is well below market demand. The drop in catch rates during the 1960s stimulated research into the large scale hatchery production of seed for both farming and reseeding. At present red sea bream is the most important hatchery reared marine teleost. In 1979 farming produced a harvest of about 12 000 t. In addition, 10 million seedlings were released into coastal waters to enhance the natural fishery.

The red sea bream is a member of the family Sparidae and is closely related to the snappers of Australia and New Zealand. The phenotypic similarity between red sea bream and New Zealand snapper (*Chrysophrys auratus*), and the high demand for sea bream in Japan, suggest that snapper farming and reseeding may be appropriate aquaculture ventures in New Zealand. The development of any such industry would depend on a hatchery supply of seed.

This publication describes the hatchery rearing of red sea bream larvae, and the reseeding operations, with specific examples from Shizuoka Prefecture. Methods used at the Shizuoka Prefectural Saibai Gyogyo Centre for the culture of food for larvae of red sea bream are discussed in the Appendix.

## Biology of red sea bream

Red sea bream are found off both coasts of Japan, in the East China Sea, and off the coast of South-east Asia. They are most abundant in the East China Sea (40% of total red sea bream landings), the northern and western parts of the Sea of Japan, and the Seto Inland Sea. They are usually found over areas of rough sea bottom, between 50 and 150 m, where they feed on various invertebrates and small teleosts. There is a spawning migration in the Yellow Sea, but the movements and migrations of red sea bream are generally not known. There are 2 hypotheses about the population in the Seto Inland Sea: one that it is a separate population; the other that it is augmented by spawning migration from outside the area. This situation is analogous to that of snapper in the Hauraki Gulf, New Zealand.

*The generic name *Chrysophrys* is used in this publication because it is in common use in New Zealand, whereas the name *Pagrus* is commonly used by Japanese scientists.

Red sea bream can live for more than 20 years and reach a length of 1 m. Sexual maturity occurs at 3–4 years of age, at a length of about 35 cm, and a weight of 1.0–1.5 kg. In the south of their range spawning starts at the end of February and continues until April. Further north spawning starts in April and lasts until June. A 3-year-old female may produce 250 000 eggs over the spawning season, whereas a 10-year-old may produce as many as 5 million.

## The Shizuoka Prefectural Saibai Gyogyo Centre

The Japanese Government, in response to declining fish catches, has an ambitious plan to enhance the coastal fisheries by the artificial rearing and reseeding (known as saibai gyogyo) of selected high value species, such as abalone, crabs, prawns, and red sea bream. Research on aquaculture species is carried out in the National Fisheries Research Laboratories and Prefectural Fisheries Experimental Stations, and the technology, or large scale production, is applied in 9 National and 27 Prefectural Fish Farming Centres.

The Shizuoka Prefectural Saibai Gyogyo Centre was completed in 1978 at a cost of 330 million yen (about NZ$1.65 million). Two-thirds of the building costs were met by central government and one-third by the prefectural government. It is near Numazu on the north-western edge of the Izu Peninsula, some 100 km south-west of Tokyo. The site of about 5000 $m^2$ is on a small peninsula with open sea to the south and a small fishing harbour to the north.

The centre consists of a 2-storey office and laboratory block, 2 large, barn-like buildings for abalone and rotifer culture, and many outdoor concrete ponds. Filtered sea water is supplied at the rate of 90 $m^3$ per hour through an activated anthracite charcoal filter, which removes all particles greater than 30 $\mu$. Unfiltered sea water is supplied at the rate of 240 $m^3$ per hour. There is a full time staff of 18 and the centre is run on a team approach to accommodate the shifting seasonal workload imposed by the spawning biology of the species being reared. Additional part time staff are employed at specific periods, such as during abalone and red sea bream reseeding. The main species being reared are red sea bream (spring spawner), prawn *Penaeus japonicus* (summer spawner), and abalone *Haliotis discus* (winter spawner). In addition, some yellowtail (*Seriola quinqueradiata*) are on-grown from wild-caught seed and pufferfish *Fugu rubripes* are cultured on an experimental scale (Smith 1981).

# Red sea bream brood-stock and egg production

Cultured fish, including hatchery reared fish, are used as adult brood-stock, and these fish are held in outdoor concrete ponds all year. There are 4 circular ponds, each of 60-t capacity, with a diameter of 5.8 m and a depth of 2.5 m (Fig. 1). Sea water is dropped from a height of about 0.5 m into the ponds (to increase aeration) at a rate of about 2 exchanges per day. Air stones are also used to circulate water in each pond. The outflow is normally at the bottom to assist in removing waste food, but this exit can be closed off to force water out through a surface overflow pipe and a plankton trap. This system is used to collect eggs each evening in spring. The ponds, and plankton traps, are covered with a double layer of black fibreglass shade netting to reduce the light intensity, but maintain a normal day length.

Each pond contains a different year class. The recommended stocking density is 0.5–1.0 kg of females per cubic metre, at a female to male ratio of 1.5 : 1. There are no external sex characteristics; so the fish are sexed by gentle hand stripping before they spawn in spring. Males are identified by milt emitted from the vent. Stocking rates and spawning conditions for the 3 ponds are shown in Table 1.

The fish are fed once a day in summer and every second day in winter. The food is either formula food (red sea bream pellets) or a mixture of formula food and minced fish produced as a moist pellet. The formula food contains multivitamins and minerals. Low value species (such as Japanese mackerel and sardine) are used either fresh or frozen, but they must be in good condition. Poor quality fish food can be a source of disease, particularly in summer when temperatures are high.

Between late March and early June, once the water temperature is above 15 °C, spawning occurs naturally in the ponds, without the need for hormone treatment or hand stripping. Spawning usually takes place between sunset and midnight. Several males will chase and nudge a female, forcing her up to the surface and often on to her side. The female releases a stream of eggs which is covered by spermatozoa from several males. Egg production ranges from about 270 000 in small females of 3–4 years of age to 4.8 million in large females of 6–12 years. Eggs are released daily in batches of 50 000–100 000, though not all the eggs produced over a spawning season are released. Egg production figures for the 3 spawning ponds are shown in Fig. 2.

**TABLE 1: Stocking rates and spawning conditions in the 3 red sea bream spawning ponds in the Shizuoka Prefectural Saibai Gyogyo Centre in 1981**

| Pond | Age of fish | Date stocked | No. of fish | No. of males | Mean weight (kg) | Spawning period | No. of spawning days | Water temp. (°C) | No. of eggs collected ( × $10^6$) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3/4/81 | 50 | 19 | 1.31 | 6 Apr–25 May | 50 | 15.9–19.6 | 9.378 |
| 2 | 5 | 12/1/79 | 32 | 14 | 2.46 | 28 Mar–18 May | 52 | 15.4–19.6 | 18.495 |
| 3 | 6 + 7 | 14/2/78 | 44 | 15 | 3.37 | 23 Mar–3 Jun | 73 | 15.4–20.1 | 100.989 |

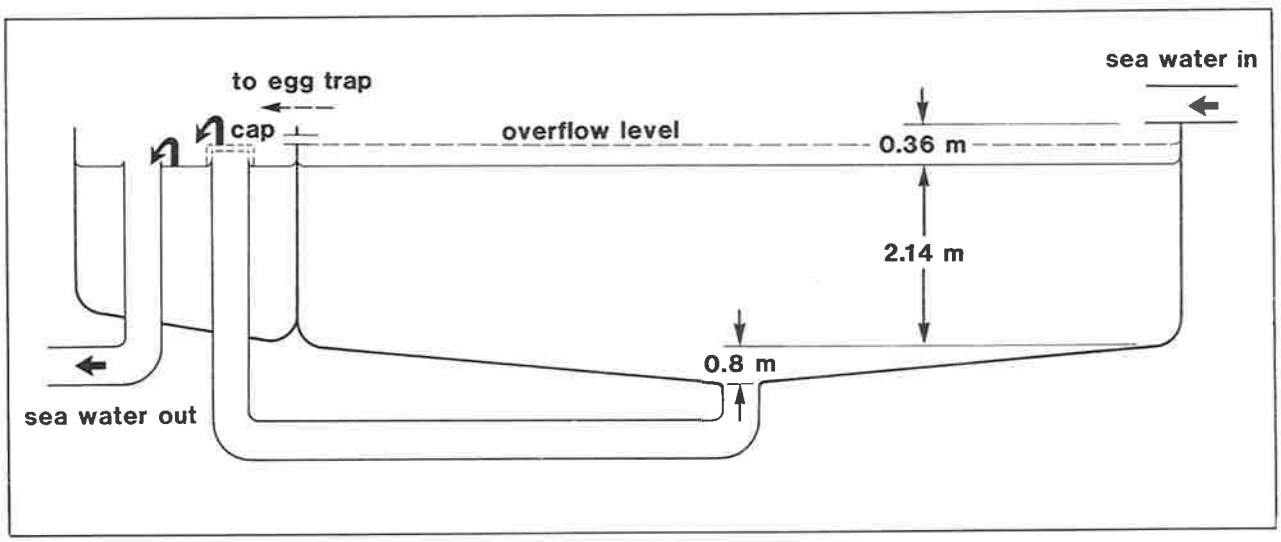



Fig. 1: A red sea bream spawning pond.

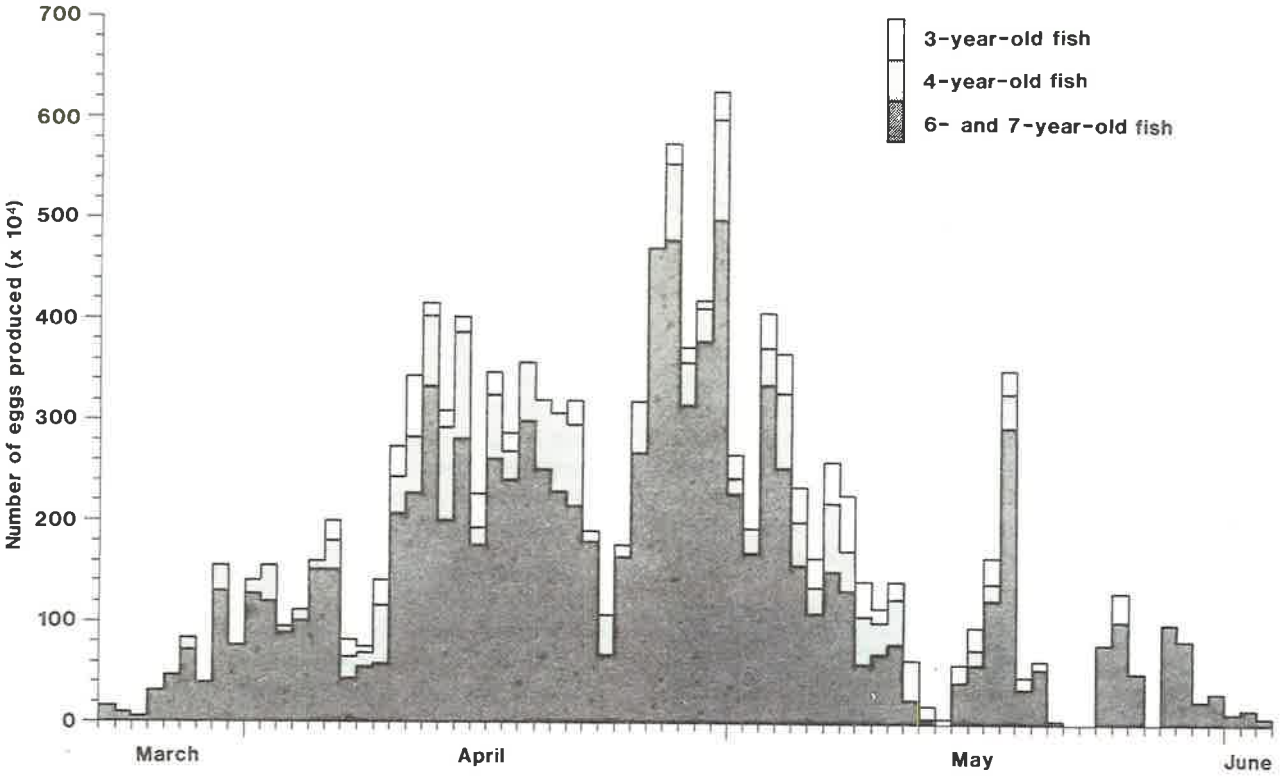



Fig. 2: Egg production and age of red sea bream for the 1981 spawning season.

Fertilisation rates are typically about 80% in young females (3–4 years old), but as low as 35% in older (over 6 years) fish. They are higher in the middle of the spawning season than at the beginning or end. The fertilised eggs, 0.9–1.0 mm in diameter, float close to the surface and are caught in the surface overflow plankton trap. This is a net 0.55 by 0.55 by 0.5 m, with an open top and a mesh size of 400 $\mu$ . It is suspended in a tank of sea water and the overflow water from the adult ponds flows through it (Fig. 3). This collects the eggs with a minimum of physical damage.

Fig. 3: Collecting red sea bream eggs. The viable eggs are skimmed off from the top 10 cm of water in the egg trap.

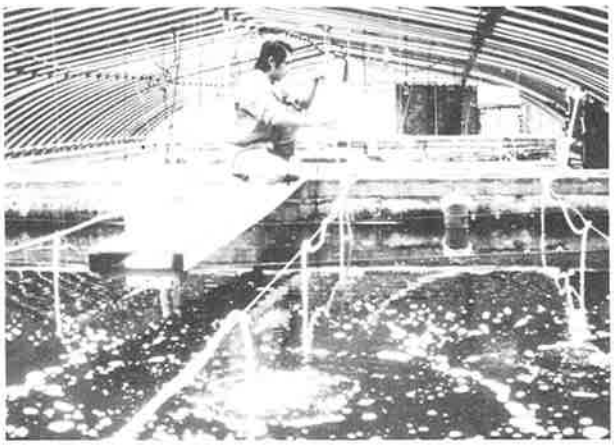
The eggs are removed from the traps each morning, poured through a strainer (which floats in a bucket of filtered sea water) to remove large particles, and weighed to estimate their numbers (1 g = 1800 eggs). The viable eggs tend to float and the non-viable eggs sink. Experiments have shown a hatching rate of 85%–90% for eggs floating in the top 10 cm or so, 38%–70% for suspended eggs, and less than 5% for eggs that sink to the bottom of the trap. After settling has occurred eggs that are to be used for larval rearing are gently skimmed from the top of the water column and weighed. The dead eggs are siphoned off from the bottom of the bucket, filtered, and weighed to estimate the total daily egg production.

At this stage the floating eggs can be placed directly into the larval rearing tanks or, as is more usual, held in an incubating cradle. This is typically a net 0.75 by 0.7 by 0.7 m, with a mesh size of 400 $\mu$, which is suspended in a l-t capacity seawater tank with aerators. Incoming filtered sea water is directed into the net to force water out through the mesh and provide adequate flow and oxygenation. The cradles and tanks are in the laboratory, where they are shaded from direct sunlight and where temperature fluctuations are kept to a minimum. Floating eggs from the cradle are stocked into the larval rearing ponds in the late afternoon or following morning. Eggs that sink to the bottom of the cradle are discarded.

# Larval rearing

Larvae are reared in outdoor concrete ponds 6 by 9 by 2 m with a seawater capacity of about 90 t. The ponds are covered with a double layer of shade netting (Fig. 4). Typical midday summer light intensities reach about 100 000 lux, but the netting reduces the intensity to about 30 000 lux at the water surface.

Water aeration is maintained by 16 air stones equally distributed close to the bottom of the pond. Food and chemicals are added through a sprinkler hose-pipe that runs the length of the pond about 0.5 m above the water surface. The water in the pond is not exchanged during the first week after hatching. After this period water is added daily and exchanges are slowly increased to about 3 per day towards the end of larval rearing (Table 2).



Water falls into the pond at one end through a microfilter and is siphoned out at the opposite end through a lantern net. This net (30 by 30 cm by 2 m deep) is changed every 4–5 days initially, but daily towards the end of the larval rearing period. As the larvae grow, the mesh size is increased to allow greater water exchange. A 0.3-mm mesh is used for the first 10 days after hatching, a 0.5-mm mesh for the next 7 days, and a 1.0-mm mesh thereafter. The bottom of the pond is siphon cleaned daily from the twentieth day after hatching. When the larvae are less than 10 mm long the aeration is stopped during cleaning so that the larvae rise to the surface and losses are minimised.

*Chlorella* spp. are added to the ponds to a density of 300 000–500 000 cells per millilitre 1 day before the red sea bream eggs. Eggs are stocked at a density of 20 000–30 000 per cubic metre to give a larval density of 20–30 per litre. A small sample of eggs is kept aside to test the hatching rate, which is usually above 80%. The eggs hatch about 2 days after fertilisation, though hatching time varies with water temperature: at 14.0 °C hatching takes 95 hours, but at 20.0 °C it takes only 39 hours.

Hatching time ($HT$) can be estimated from the formula:

$HT$ (hours) $= 427/t - 9$, where $t$ is temperature (°C).

Fig. 4: Cleaning a red sea bream larval rearing pond.

**TABLE 2: Rearing details for 1 red sea bream larval pond at the Shizuoka Prefectural Saibai Gyogyo Centre in 1981**

| Date | Days after hatching | Water temp. (°C) | pH | Salinity (°/oo) | Volume of water added ($m^3$) | Rate of water exchange per day | Density of *Chlorella* ($\times 10^4$/ml) | Volume of *Chlorella* ($m^3$) | No. of rotifers ($\times 10^8$) | Wt. of frozen rotifers (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| 28 Apr* | | | | | | | | | | |
| 30 Apr | 0 | 17.5 | 8.34 | 33.6 | 0 | 0 | 36 | 0.5 | 0 | 0 |
| 6 May | 6 | 17.6 | 8.38 | 32.2 | 3.6 | 0.04 | 41 | 2 | 6.4 | 0 |
| 11 May | 11 | 18.7 | 7.98 | 31.8 | 8.9 | 0.10 | 48 | 3 | 3.0 | 0 |
| 14 May | 14 | 18.4 | 7.88 | 31.0 | 12.6 | 0.14 | 27 | 5 | 7.6 | 0 |
| 18 May† | 18 | 17.7 | 7.84 | 33.3 | 24.5 | 0.27 | 49 | 4 | 9.4 | 0 |
| 22 May | 22 | 17.8 | 7.90 | 34.7 | 40.8 | 0.45 | 25 | 5 | 14.8 | 0 |
| 25 May | 25 | 18.7 | 7.98 | 33.6 | 57.6 | 0.64 | 35 | 5 | 17.6 | 0 |
| 27 May | 27 | 19.4 | 8.15 | 23.8 | 51.0 | 0.57 | 33 | 4 | 17.9 | 0 |
| 28 May | 28 | 19.6 | 8.02 | 33.2 | 25.2 | 0.28 | 52 | 3 | 17.5 | 0 |
| 1 Jun | 32 | 18.8 | 8.05 | 34.4 | 86.4 | 0.96 | 4 | 0 | 13.0 | 0 |
| 5 Jun | 36 | 19.7 | 8.00 | 34.1 | 100.8 | 1.12 | 0 | 0 | 3.2 | 3.6 |
| 8 Jun | 39 | 21.1 | 8.10 | 33.3 | 220.8 | 2.45 | 0 | 0 | 0 | 4.1 |
| 9 Jun§ | 40 | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 18.55 | 8.06 | 33.3 | 1 867 | 20.76 | | 106 | 380 | 31.1 |

* 2.55 $\times 10^6$ eggs stocked (hatching rate 91.7%).
† Start of chemical treatment (sodium nifurstyrenate at 1.5 ppm) to clean tank.
‡ Not measured.
§ Transfer to sea cage.

Development ceases below 10 °C and mortality levels are very high above 25 °C; optimum temperatures are between 15 and 18 °C.

The newly hatched larvae are 2.0–2.3 mm long and feed off their yolk sacs for 3–4 days. They float around the pond in the circulation produced by the air stones. Survival over this stage is almost 100%.

Rotifers are added to the ponds 2 days after hatching to ensure an adequate food supply at the onset of larval feeding. *Chlorella* are added daily throughout the rotifer feeding period to maintain their density at about 500 000 cells per millilitre. They are pumped directly into the ponds from the outdoor *Chlorella* tanks. They have a beneficial effect on larval culture by acting as a food source for rotifers and probably stabilising pH in the ponds. They also increase larval survival rates (Kittaka 1977).

In early work on the hatchery rearing of red sea bream larvae, mussel and oyster larvae, and in some hatcheries barnacle larvae, were used as a preliminary food supply for 2–4 days before the rotifers were added (Kittaka 1977). This additional food supply is unnecessary because rotifers breed in the ponds and so provide a smaller food particle which is suitable for the red sea bream larvae. Rotifers are used as the principal food source for as long as possible because they give good growth and survival rates in red sea bream larvae and can be produced easily on a large scale. Each larva may eat 20 rotifers per day at the onset of feeding, but more than 200 per day 2 weeks after hatching. The high consumption and the loss through water exchange mean that millions of rotifers are required each day. The rotifer density in the larval ponds has to be maintained at a minimum of 5 per millilitre to avoid larval starvation; in practice, it is kept at more than 10 rotifers per millilitre. Rotifer counts are made 3 times a day for each larval pond and the required number (in a volume of known rotifer density) is pumped into the pond from the rotifer production unit. The required number of rotifers in each larval rearing pond is estimated from the formula:

$$N_r = R_d N_l (R_w + 1),$$

where $N_r$ is the total number of rotifers required per day, $R_d$ is the number of rotifers eaten per larva per day, $N_l$ is the number of red sea bream larvae in the pond, and $R_w$ is the water exchange rate. The value of $R_d$ is calculated from the formula:

$$R_d = 0.3927 L^{3.676},$$

where $L$ is the mean length of larvae in the pond.

Rotifers are used as a food source for up to 35 days after hatching. Some 20 days after hatching, when the larvae have reached a length of about 6 mm, the rotifer diet is supplemented with *Tigriopus japonicus*, a marine copepod. If *Tigriopus* is used as the sole food source the number eaten per larva per day is estimated from the formula:

$$T_d = 0.6728 L^{3.4658},$$

where $L$ is the mean total length of larvae. In practice, when *Tigriopus* is used to supplement the rotifers, the quantity required is decided from the total weight of rotifers required minus the actual weight of rotifers used (1 rotifer = 0.003 mg, 1 *Tigriopus* = 0.034 mg).

Nauplii of the brine shrimp *Artemia salina* can be used as a food source between 20 and 35 days after hatching, but cannot be used exclusively for more than 4 or 5 days (Fukusho, Hara, and Yoshio 1976). They give good growth rates, but can cause high larval mortalities. A comparison of 2 groups of larvae, 1 fed on *Artemia* and the other on copepods, from 20 to 34 days after hatching, showed a 15% survival rate in the former and a 50% rate in the latter (Kittaka 1977).

| Artificial food (g) | No. of *Artemia* ($\times 10^6$) | Wt. of *Tigriopus* (g) | Wt. of frozen *Tigriopus* (g) | Wt. of frozen red sea bream eggs (g) | Wt. of clam (g) | Wt. of opossum shrimp (g) | Wt. of sand lance (g) | Larval length (mm) | No. of larvae ($\times 10^6$) | % survival |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.87 | 2.34 | 100 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.68 | 2.04 | 87.3 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.14 | 1.54 | 65.8 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.83 | 1.14 | 48.8 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5.03 | 0.90 | 38.4 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.56 | 0.70 | 29.9 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.84 | —‡ | — |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9.11 | 0.41 | 17.7 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — | — | — |
| 200 | 91 | 1 600 | 0 | 0 | 0 | 0 | 0 | 11.62 | 0.40 | 17.0 |
| 300 | 78 | 140 | 600 | 900 | 900 | 900 | 0 | 13.78 | 0.23 | 10.0 |
| 300 | 99 | 0 | 400 | 1 250 | 0 | 1 300 | 900 | — | — | — |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15.23 | 0.21 | 8.99 |
| 2 600 | **936** | 4 580 | 1 900 | 7 410 | 2 100 | 6 000 | 2 700 | | | |

Some 30–35 days after hatching, at a length of 10–12 mm, the larvae (or fry at this stage) are weaned on to the juvenile diet. The rotifer, *Tigriopus,* and *Artemia* diet is slowly phased out over 2 weeks as the juvenile diet is introduced. Red sea bream fry crumbs, frozen fish eggs (usually excess production from the spawning ponds), and finely minced opossum shrimp *Neomysis japonicus*, clam *Tapes philippinarum*, and sand lance *Ammodytes personatus* are used over the weaning period. This is a critical stage of larval rearing: too much food can rapidly cause pollution in the ponds; too little food can lead to cannibalism and starvation. The total amount of moist food added per day is 70%–80% of the total weight of fry in the pond.

Forty days after hatching, at a length of about 15 mm, the fry are ready for transfer to sea cages. In some other saibai gyogyo centres larvae are transferred to larger ponds at about 8 mm and then to sea cages at about 20 mm. The larval rearing phase for 1 pond at the Shizuoka Prefectural Saibai Gyogyo Centre is summarised in Fig. 5 and Table 2.

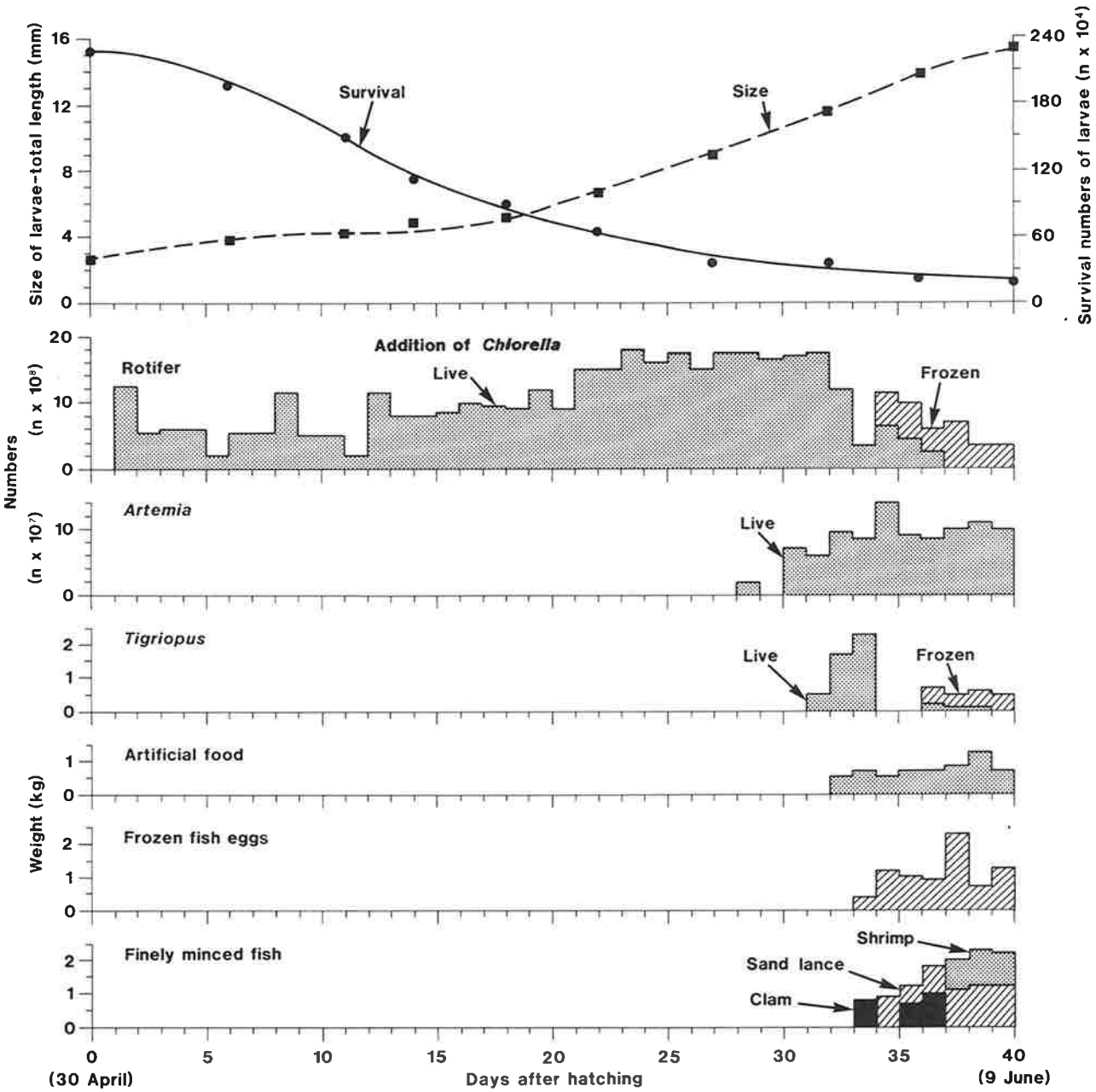



Fig. 5: Summary of red sea bream larval rearing for 1 pond over the 1981 season.

Physical conditions and food supply are monitored daily in each pond. The larvae are sampled every 3–5 days to measure growth rate and development, and their numbers are estimated every 4–5 days after dark, when the larvae are equally distributed throughout the pond. Substantial resources have to be allocated to larval food production; 2 staff are employed on larval rearing and between 5 and 7 on the production of larval food (*Chlorella*, rotifers, and *Artemia*). Artificial pelletised food is available for even the small larval stages, but it does not give good growth or survival rates and needs to be supplemented with live rotifers. In addition, it causes pollution problems, because uneaten food settles out and encourages the growth of bacteria.

# On-growing in sea cages

Fry are removed from the ponds by lowering the water level and herding the fish by seine net so that they can be either scooped up by bucket or siphoned out into transport tanks. An estimate is made of the number of fry harvested. Some are transported by boat to sea cages in neighbouring bays; others are taken to more distant sites by road and then boat. The centre has a 10-m vessel with holding tanks to transport live fish. Fry are carried in fine nets held on a wooden frame in the tanks. Those to be transported by boat are carried at a density of 25 000–30 000 per tonne of sea water for journeys of 1–2 hours and at densities of up to 50 000–100 000 per tonne for journeys of 30 minutes or less. For road transport fry are carried at a density of 25 000–30 000 per tonne. Oxygen is bubbled into the water and if necessary a small amount of freshwater ice may be added to minimise temperature increase.

The criteria used to select cage sites are that they are sheltered from wave action; have good tidal circulation; are away from freshwater, chemical, and sewage run-off; and are out of shipping channels. Cage sizes vary from small experimental cages 3 by 3 by 3 m to large commercial cages 5 by 5 by 5 m with nets suspended from a floating framework of galvanised iron supported on polystyrene floats. Five to 10 cages are joined and anchored fore and aft to lie into the prevailing wind. Mesh size is increased as the fry grow, to facilitate water exchange and reduce fouling (Fig. 6).

Fifteen-millimetre fry are stocked at a density of 2000–4000 per cubic metre in 2-mm-mesh cages. As the fry grow their density is reduced by transfer to other cages. They are fed at least 4 times a day on finely minced fish at an initial rate of 100% of total body weight per day. The rate is reduced to about 20% of total body weight per day. On this diet growth is rapid, from 15 mm in June to 5–10 cm by August, at which size and time the juvenile red sea bream are ready for release. In a typical example from Shizuoka Prefecture, 96 000 seed fish were raised from an average fork length of 2 cm on 1 July to 8 cm on 19 August with a survival rate of 78.5%.

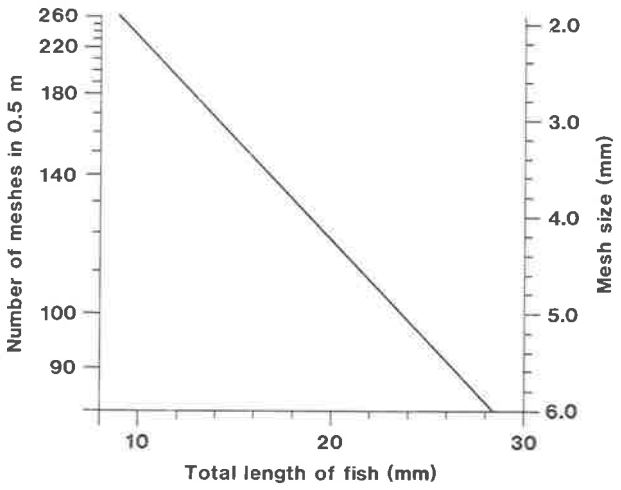



Fig. 6: Mesh sizes for juvenile red sea bream cages.

# Disease

The Shizuoka Prefectural Saibai Gyogyo Centre has disease specialists who monitor and treat diseases in all species being reared. There are fewer major disease problems with red sea bream than with other cultured finfish. In adults most problems that arise can be attributed to handling stress or poor diet. In the larval stages *Vibrio* sp. can cause high mortalities. The critical symptom of a swollen abdomen appears in larvae 5–10 mm long. The disease can be treated by the addition of 1.5 ppm nifurpirinol to the larval food (rotifers, *Tigriopus,* and *Artemia*). Daily siphon cleaning of the tanks can help reduce the disease, but ultraviolet irradiation of incoming sea water has little or no effect. Sodium nifurstyrenate is being tested as a treatment for *Vibrio* sp. in the larval rearing tanks. It is dissolved in fresh water and sprayed on to the larval rearing tanks through the sprinkler feeding system to give a final concentration of 1.5 ppm. Water flow in the tanks is stopped for 24 hours during treatment.

Red sea bream juveniles on-grown in sea cages can suffer from bacterial diseases (caused by *Vibrio* sp. and *Flexibacter* sp.) during their first year. Typical symptoms are ulcerations of the skin for infections of *Vibrio* sp. and eroded mouth, frayed fins, and tail rot for those of *Flexibacter* sp. These can be treated by the addition of oxytetracycline hydrochloride to the food at a rate of 30–50 mg per kilogram of juveniles per day for 5–7 days.

# The red sea bream fishery and reseeding

The annual red sea bream fishery in the Tokai region on the Pacific coast of central Japan has declined from a peak of 3270 t in 1965 to about 500 t. Landings from the Izu Peninsula coastal fishery of Shizuoka Prefecture, which makes up a small part of the Tokai fishery, have declined from a maximum of 240 t to about 30 t per year. The Izu Peninsula fishery is centred on eastern Suruga Bay and east coast, Izu Peninsula. Most fish are caught by set net and angling in less than 100 m and are 1–3 years old.

The aim of the reseeding programme in Shizuoka Prefecture is to restore the coastal fishery to earlier levels. The programme is monitored by the Shizuoka Prefectural Fisheries Experimental Station, Izu Branch which has a staff of 13 and carries out research on the commercially important resources of finfish and shellfish. Surveys of the red sea bream fishery have been made to estimate numbers, growth rates, movements, and mortalities. The reseeding programme in Shizuoka Prefecture is integrated with that of neighbouring Kanagawa Prefecture, where there are similar declining fisheries in Tokyo Bay and off the west coast of Miura Peninsula. Releases began in 1977 in Kanagawa Prefecture and in 1978 in Shizuoka Prefecture (Fig. 7).

## Release sites

Many of the released fish are tagged to estimate growth and mortality rates and the effect on the fishery. The minimum recommended release size is 4 cm,

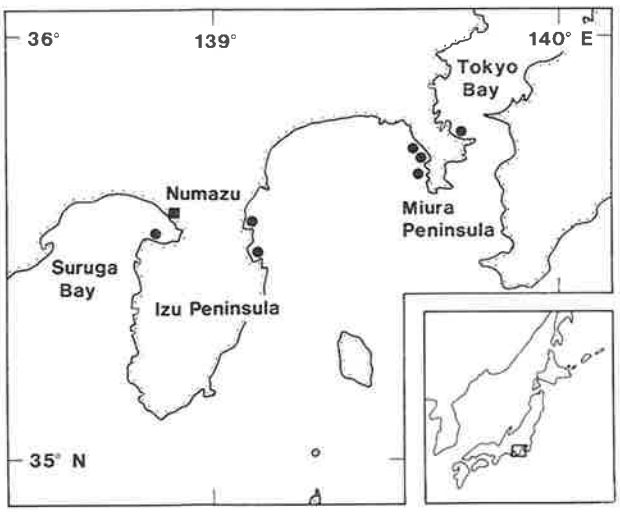



Fig. 7: Red sea bream release sites around the Izu and Miura Peninsulas.

though 8–10 cm is preferred for tagging (Fig. 8). Fish are tagged with small (1.5-cm long) plastic anchor tags, which are injected into the dorsal muscle with a Banok Q3 103-S tagging gun. Code numbers can be written directly on the tag, and different coloured tags indicate release batches or sites. Up to 10 staff work on the tagging programme. Tagging operators wear cotton gloves to reduce scale damage to the fish and to protect their hands from spines. One person can tag 1000–2000 fish per day.

Where fish are to be released close to the on-growing sites, the cages are towed to the release area. The nets are raised and the fish are scooped out in buckets to reduce scale damage. They are tagged and carefully placed over the side. Fish that are not to be tagged are released by lowering the net from the frame. For more distant release sites, fish are scooped up in the same way and transported in the hold of the vessel. Sea water is pumped continuously through the hold. The fish are tagged on board and placed over the side at the release site.

In the Seto Inland Sea, experiments have been carried out on the audio-signal training of red sea bream. Juveniles held in enclosed bays or sea cages have been subjected to sound pulses from an underwater speaker just before feeding. Results have shown that over a 2-week period most of the fish become conditioned to respond to the sound. It is intended to lure juveniles away from the hatchery rearing site to more suitable nursery areas by slowly moving the underwater speakers.

Release sites are selected from experimental fishing and diving surveys. Ecological studies and tagging experiments have been made on natural populations of red sea bream. These have found fry, 2–4 cm long, in water depths of 1–5 m between May and June, fish of 4–7 cm in 5–10 m between June and August, and fish of 6–13 cm in 8–20 m between July and October. Larger fish (over 12 cm) move into deeper water, down to 60 m, over the first winter. Several release sites, ranging in depth from 5 to 30 m, have been tested from August to October.

Four release areas have been tested by the Shizuoka and Kanagawa Prefectural Fisheries Experimental Stations and Saibai Gyogyo Centres, 1 in each of the 4 red sea bream fishing areas. Release sites varied from eelgrass beds at a depth of less than 5 m to natural reef and mud-sand areas between 10 and 20 m (Table 3). All were areas inhabited by wild juveniles (Kawajiri 1981). The best returns (2.99% of released fish) were recorded from natural reef and mud-sand areas. Growth rates varied between release sites; 2-year-old fish in eastern Suruga Bay were about twice the weight of 2-year-old fish in other areas. The 0-group fish remained in the release area; most recaptures were within 2 km of the release site and there was a maximum movement of 10–15 km. There is a general movement into deeper water in autumn, when some tagged fish are caught under culture rafts. Few fish are recaptured over winter. Most 1-year-old fish were taken within 5 km of the release site, with a maximum movement of 25–30 km; and most 2-year-olds were taken within 8 km of the release site, with a maximum movement of 30–35 km (Kawajiri 1981).

From these results it has been recommended that commercial and sports fishing be banned within 3 km of the release site for 11 months from the release date. To help enforce this recommendation, the work of the

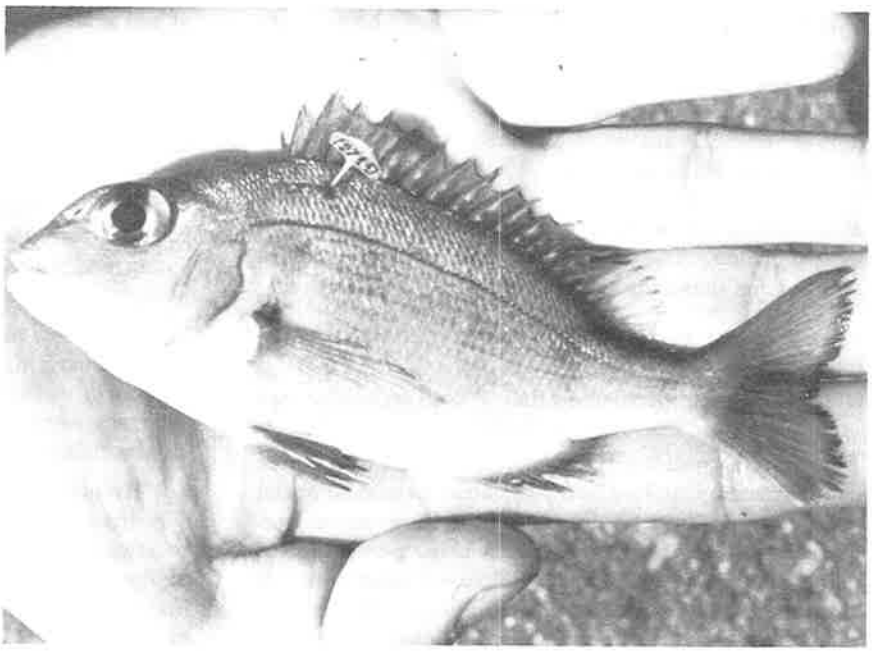


Fig. 8: A tagged juvenile red sea bream ready for release.